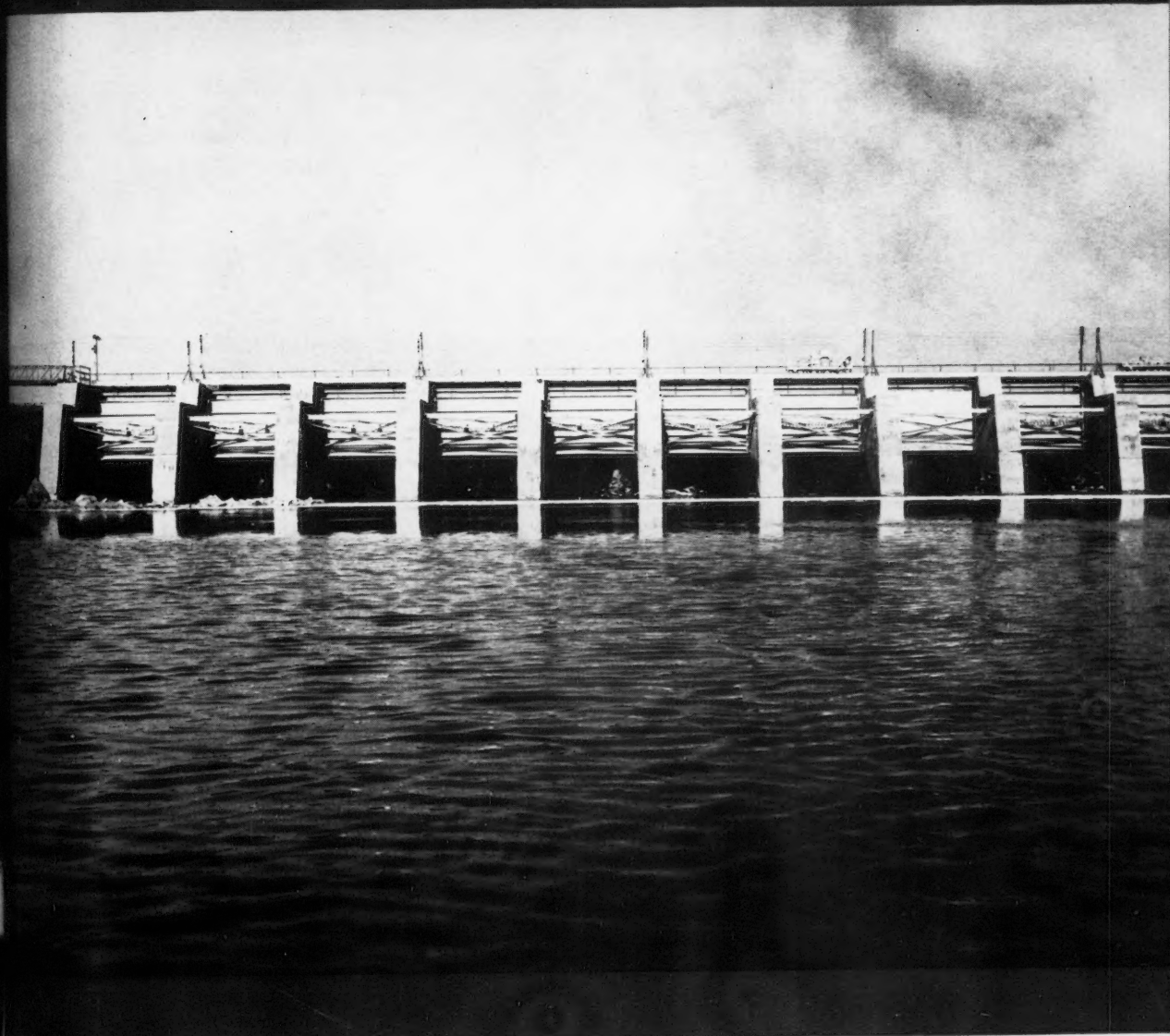


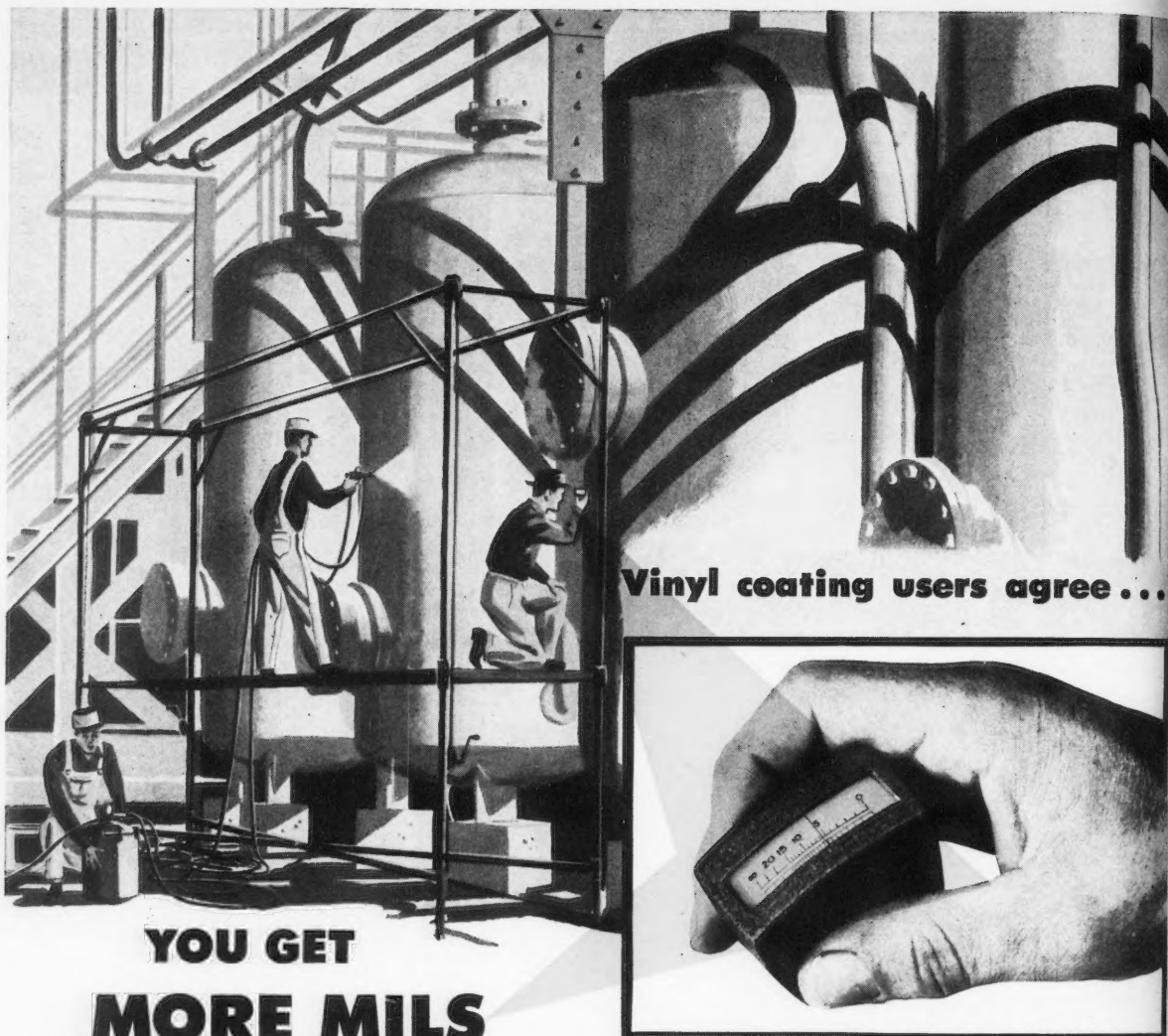
Corrosion

Official Publication
NATIONAL ASSOCIATION OF CORROSION ENGINEERS



NOVEMBER, 1954

No. 11



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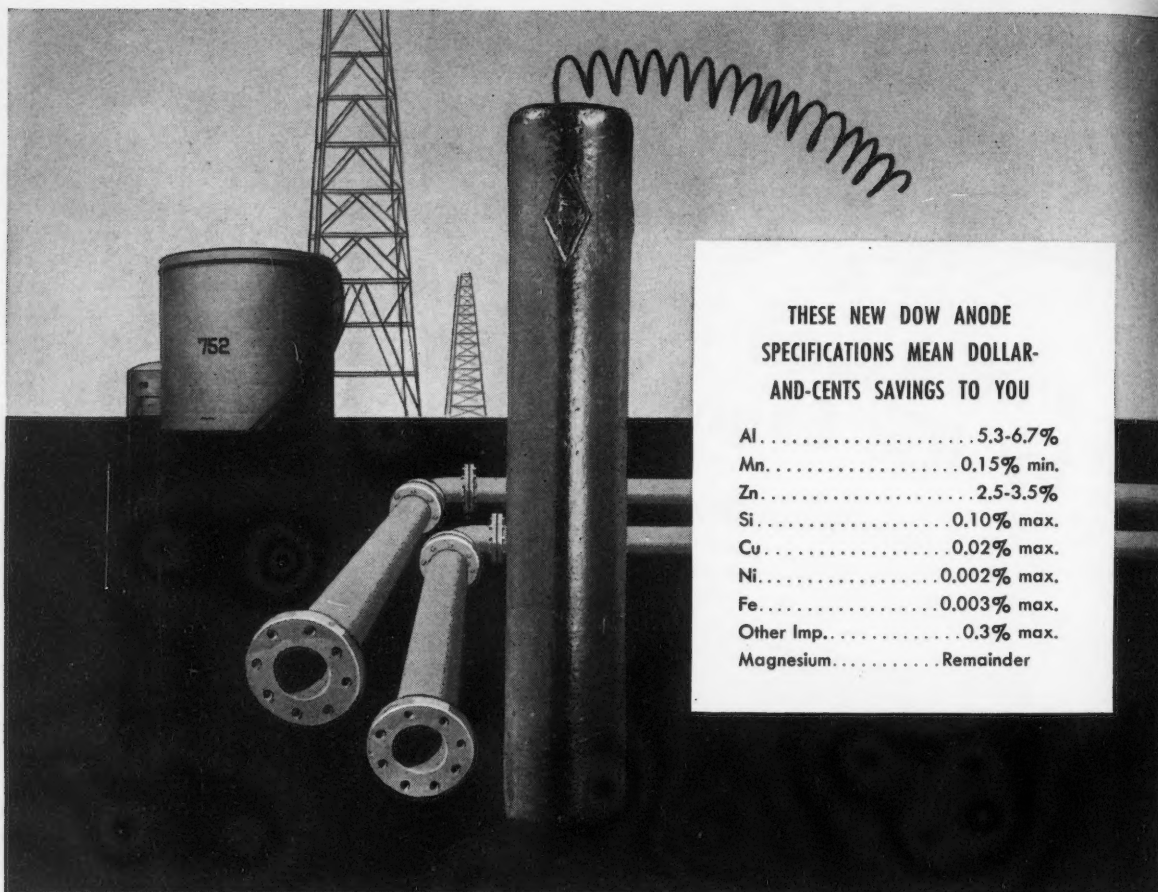
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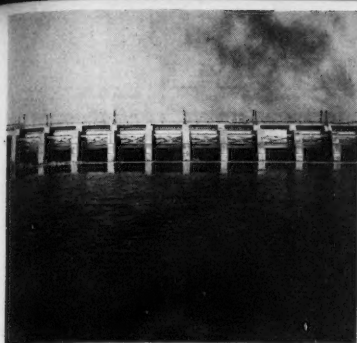
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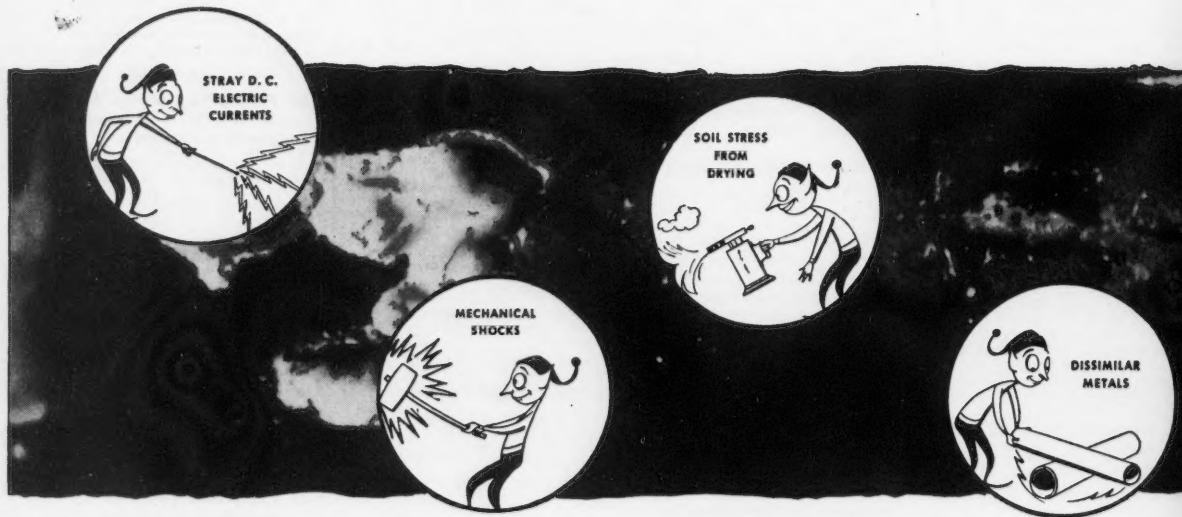
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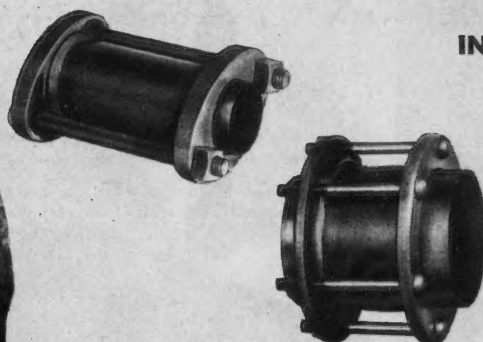
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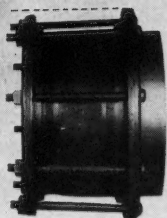
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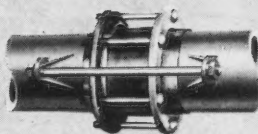
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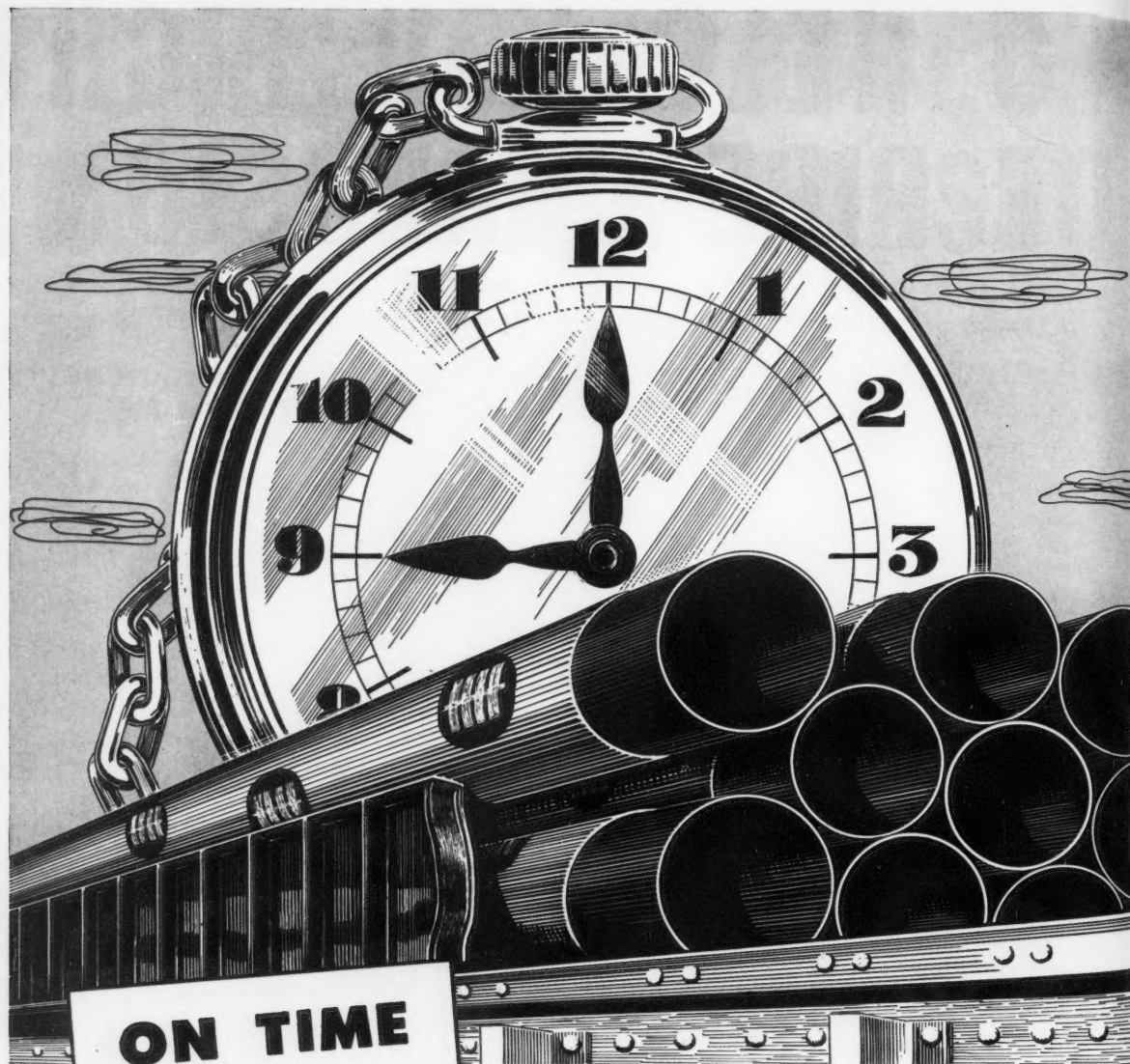


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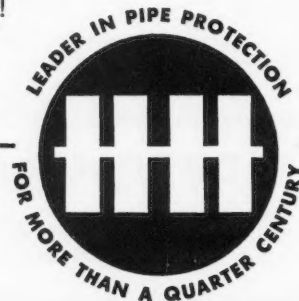
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Bromine—The high resistance of Monel shipping drums to dry bromine has enabled bromine manufacturers to ship this dangerous corrosive in original purity, without fear of contamination or breakage, while cutting shipping costs in some cases by as much as 50%.*

Fluorine—Because nickel and Monel are highly resistant to ignition by fluorine, they are preferred materials for storage cylinders, piping and valves when handling fluorine under pressure.

Sodium Chloride—Potassium Chloride—Manufacturers rely on Inco Nickel Alloys to help preserve product purity during the entire refining operation. High-nickel alloys are counted on to assure long service life for such equipment as brine storage tanks, pumps, valves, filters, evaporators and driers.

Hydrogen Fluoride and Hydrofluoric Acid—Monel is more widely applicable to the handling of anhydrous HF and hydrofluoric acid solutions over a wide range of temperatures and concentrations than any other alloy.

Magnesium Chloride—Because Inconel is free from stress corrosion cracking in boiling magnesium chloride solutions, it has been accepted as a standard material for evaporating magnesium chloride.

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If your operations with halogens or their compounds seem to indicate the desirability of employing one of the Inco Nickel Alloys, it will be advisable to place equipment orders with your supplier well in advance of scheduled use. Distributors of Inco Nickel Alloys can supply the latest information on availability from warehouse and mill.

*Other materials which are shipped in nickel drums include: acetyl chloride, benzyl chloride, benzoyl chloride, pyrosulfuryl chloride, thionyl chloride, phosphorus trichloride, phosphorus oxychloride, and thiophosphoryl chloride.

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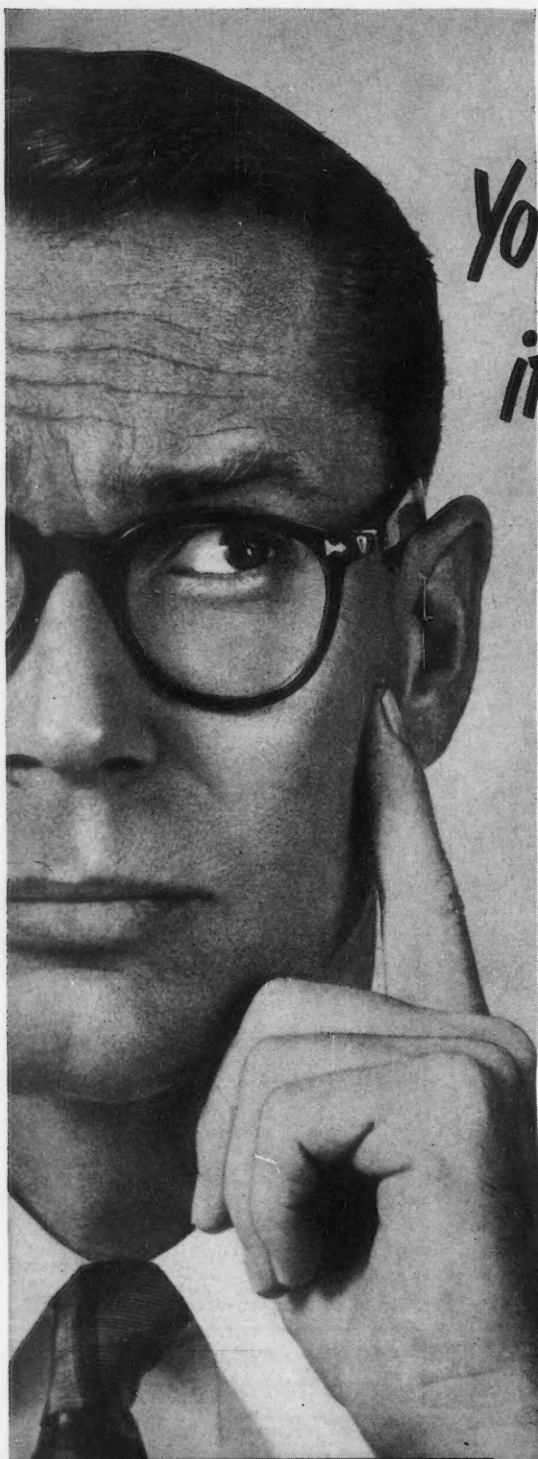


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Inorganic Acid Chlorides in Which Satisfactory
Uses of Monel and Nickel Have Been Recorded

Corrosive Media	Monel	Nickel
Aluminum Chloride	Yes	.....
Ammonium Chloride	Yes	Yes
Antimony Chloride	Yes	.....
Arsenic Trichloride	Yes	Yes
Magnesium Chloride	Yes	Yes
Manganous Chloride	Yes	.....
Nitrosyl Chloride	Yes	Yes
Phosphorus Oxychloride .....	.....	Yes
Phosphorus Trichloride .....	.....	Yes
Silicon Tetrachloride .....	.....	Yes
Sulfur Monochloride	Yes	Yes
Sulfuryl Chloride	Yes	Yes
Tin Tetrachloride	Yes	Yes
Titanium Tetrachloride	Yes
Zinc Chloride	Yes	Yes



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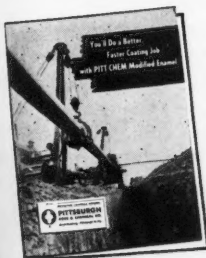


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CORROSION—November, 1954

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- (c) To encourage special study and research to determine the fundamental causes of corrosion, and to develop new or improved techniques for its prevention.
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- (e) To promote standardization of terminology, techniques, equipment and design in corrosion control.
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Topic of the Month

Galvanic Anodes Control Induced Voltages On Pipe Lines

By E. H. THALMANN*

WELL-COATED transmission pipelines constructed on the same right-of-way or adjacent to electric power transmission lines can be subjected to induced voltages of considerable magnitude during lightning storms and when ground faults occur on the power line. These potentials can develop because the pipeline, a paralleling metallic conductor is in effect a single turn secondary of an air core transformer, the power transmission line acting as the primary. The magnitude of induced voltage varies with the length of exposure, fault current, separation of power line and pipeline and soil resistivity. With bare pipelines the secondary is effectively short-circuited by the pipeline-to-earth resistance and the induced voltage, being consumed by impedance drop, does not result in appreciable voltage-to-ground of the pipeline. On well-coated pipelines, however, the distributed resistance-to-earth is relatively high, the pipeline behaving much like an open-circuited secondary so that a substantial portion of the induced voltage appears as a voltage between the pipeline and ground.

The voltage-to-ground on well-coated pipelines resulting from induction can be greatly reduced by lowering the distributed resistance-to-earth of the pipeline. Groups of galvanic anodes distributed along the pipeline are well adapted to this purpose because they furnish cathodic protection to the pipeline in addition to providing a path for induced currents to enter or leave the pipeline without danger of arcing or burning.

A recently constructed gas transmission line with a high-resistance coating paralleled high-voltage power transmission lines for approximately thirty miles. Voltage induced in the pipeline from a ground fault on the power line was sufficient to arc across insulating flanges at the line terminals. Two methods were used to control these inductive effects:

1) installation of groups of galvanic anodes along the pipeline to reduce its resistance-to-earth, at the same time providing cathodic protection to the pipeline, and

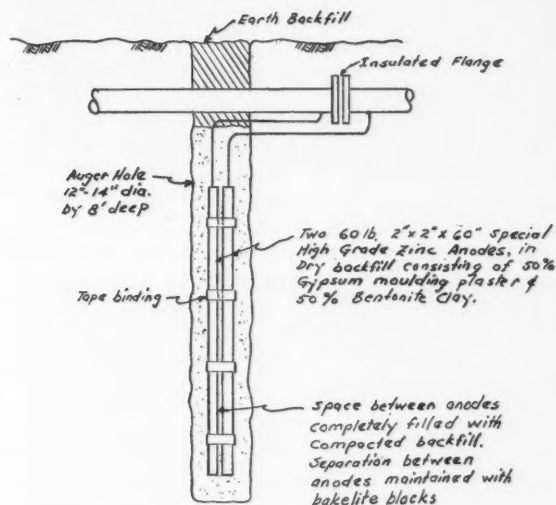


Figure 1—Zinc anode pair connected across insulated flange.

2) installation of buried zinc anode pairs across insulating flanges, which function both as lightning arresters and provide low-resistance electrolytic shunts of high current capacity across the flanges for currents induced from the power line.

Thirty-five groups of galvanic anodes were distributed along a 50-mile section of pipeline, 29 of the groups consisting of zinc anodes and six groups consisting of magnesium anodes. The number of anodes per group ranged from three to seven. This provided sufficiently low grounding resistances compared with the 60-cycle longitudinal impedance of the pipeline to reduce the voltage appearing between pipeline and ground to relatively low values during power line ground faults. Cathodic protection potentials in the order of one volt to a copper-sulfate electrode were realized on the pipeline.

Additional protection from induced currents at insulating flanges was provided by buried zinc cells such as shown in the accompanying Figure 1. The resistance between a single pair of anodes is a fraction of an ohm, substantially independent of soil resistivity, being controlled by the resistivity of the backfill used. This low resistance across the flange does not constitute appreciable drain on the cathodic protection system, as would a metallic resistor, because current picked-up on the unprotected side of the flange in flowing through the cell causes cathodic polarization of the zinc connected to the protected side of the flange. D-c voltages in the order of 0.5-volt thus can be maintained across the flange without appreciable current flow.

*Ebasco Services, Inc., New York, N. Y.

Corrosion of Refinery Equipment By Sulfuric Acid and Sulfuric Acid Sludges*

By V. J. GROTH and R. J. HAFSTEN

Introduction

THE PURPOSE of this article is to discuss the problems resulting from corrosion of equipment handling sulfuric acid or acid sludges and present information for material selection. Although no definite recommendations are given, the information presented should serve as a guide or starting point for future investigations. In many cases, however, the experience is complete enough to permit material selection without further tests.

Oil refineries consume large quantities of sulfuric acid. In some of the larger refineries this may amount to well in excess of 200 tons of acid daily. Sulfuric acid is used in the acid-treating processes whereby oil stocks are treated with sulfuric acid for one or more of the following reasons:

- 1) to improve color
- 2) to remove resinous, asphaltic, or gum-forming materials
- 3) to reduce mercaptan content
- 4) to improve stability
- 5) to change physical properties, and
- 6) to remove sulfur effects.

In treating oil stocks for the foregoing reasons, acid sludges are formed. These sludges are usually heavy viscous substances which are separated from the treated oils and then processed further. If economical, sulfuric acid is recovered from the sludges by hydrolysis and separation, after which it is concentrated for reuse.

Sulfuric acid is also used as a catalyst for the alkylation reaction of isobutanes and butylene.

In addition to the acid-treating, alkylation and acid-reclamation processes, additional corrosion problems are encountered in acid-producing units and equipment used in the disposal of acid sludges.

In the first part of the paper general corrosion problems associated with tanks, lines, valves, pumps and heating coils are discussed. The second part of the paper contains corrosion data which may be of some value in corrosion investigations and also presents the service data on sulfuric-acid handling equipment which were obtained from various refineries.

Tanks for Strong Sulfuric Acid and Strong Sulfuric-Acid Sludge

Plain carbon steel is extensively used for the fabrication of tanks and vessels which handle either strong sulfuric acid or sludges which contain strong sulfuric acid. At room temperature and acid concentrations as low as 65 percent the corrosion rates of



V. J. GROTH—He has been engaged in engineering development work with Standard Oil Co. (Indiana) at Whiting, Indiana since 1950. A graduate of Michigan State College in 1948 with a BS in chemical engineering, he joined his present employer on graduation.



RAYMOND J. HAFSTEN—Presently Assistant Chief Engineer in the Whiting Refinery Engineering Division, Standard Oil Company (Indiana).

Abstract

Characteristics of sulfuric acid solutions encountered in refineries, the types and kinds of containers, piping, valves, heaters and other equipment used to handle it are considered by the authors with respect to their corrosion resistance and certain other related qualities. Materials of construction for construction, fabrication and design details of the various vessels and equipment are discussed with relation to the several concentrations, temperatures, pressures, velocities and other peculiarities of the sulfuric acid solutions encountered in petroleum refineries.

Results of field experience and laboratory tests are reported and recommendations are made respecting the selection of materials, optimum design, expected service life, maintenance procedures and economic considerations with respect to many materials. Precautions to be taken with welded and riveted tanks, fabrication and design considerations related to lead and other linings; examples of good and bad service and reasons for failures for containers, pipes, valves, pumps and heater coils are given. Galvanic effects encountered in connection with certain equipment are reported and remedial measures recommended.

Figures showing examples of failures and charts and tables of data are included.

steel are low enough to permit its use. However, because of the higher temperatures involved and the possibility of accidental dilution of the strong acid with water, steel is most generally used in the refinery for acid concentrations of 75 percent and greater.

Riveted steel tanks are commonly used to handle strong sulfuric acid and strong sulfuric-acid sludges. Although strong sulfuric acid at moderate temperatures is not very corrosive to steel, a considerable amount of maintenance may be experienced with riv-

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Figure 1—Corrosion at the riveted seams of a tank used in strong acid service.

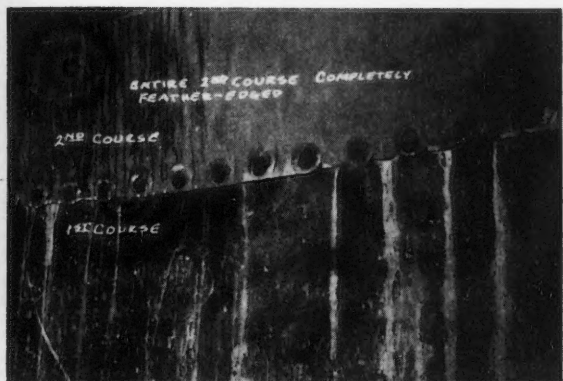


Figure 2—Feather edging of the riveted seams of a tank in strong acid service.

eted tanks. The corrosion shown in Figures 1 and 2 occurs at the riveted seams and is due to the action of weak acid, even though the tanks handle only strong acid. The mechanism is one in which the strong acid enters the capillary space formed by the overlapping plates at the seams. In this space the strong acid has access to the moisture in the air—with the resulting formation of weak, highly corrosive sulfuric acid which attacks the plate and rivets at the seams. In order to stop the leakage which follows, recalking of the plate edge and redriving of the rivets are necessary. In time, the plate and rivets at the seams become corroded to the extent that further calking and rivet-driving are no longer effective. In the more severe cases failure has occurred in periods as short as six years, requiring that either the tank be scrapped or extensive repairs be made. Repairs are generally made by welding steel strips over the seams or by fillet-welding the plate edges at the seams and seal-welding the rivets. Repairs of this kind are expensive.

A type of corrosion was observed which resulted in the failure of an agitator bottom after having been in service less than two years. The agitator was used in treating an oil with 98 percent sulfuric acid. It was disclosed that the agitator contained many copper

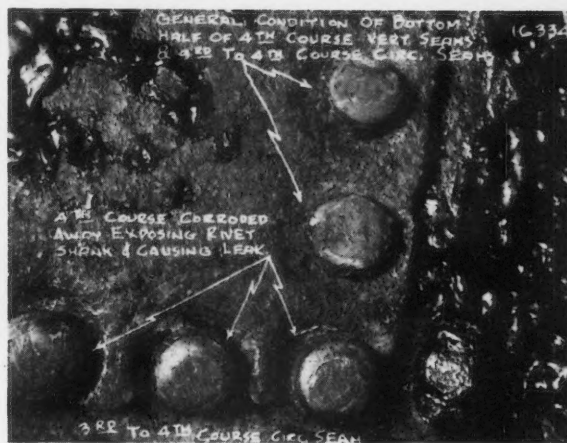


Figure 3—Galvanic corrosion which occurs between copper rivets and steel plates.

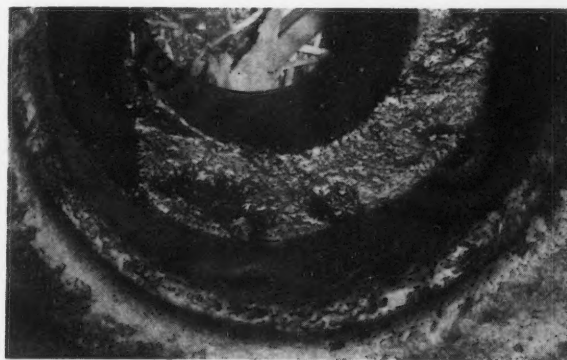


Figure 4—Selective corrosion of welds.

rivets which caused galvanic cell corrosion to take place. The galvanic action which occurred between the copper rivets and steel plates rapidly accelerated the corrosion of the steel plates, as shown in Figure 3. This was an isolated case and it is unusual for a rivet material other than steel to be used. However, reference to this occurrence is made here merely to suggest that galvanic cell corrosion must not be overlooked in the design of acid-handling equipment.

Corrosion of Welded Tanks

Other than the case just mentioned, where substitution of steel rivets for copper rivets put an end to the galvanic cell difficulties, no ready solution exists for eliminating the corrosion at the rivet seams. Although it would appear that welded construction would be the answer to such difficulties, an unusual type of corrosion has been observed in welded steel tanks. It has been noted that in some cases the welds of tanks have been preferentially attacked by the acid at a more rapid rate than the parent plate. In some instances, the weld or adjacent parent metal is uniformly corroded away; whereas in others, deep pitting or worm-holing of the weld occurs, as shown in Figure 4. Experience has disclosed many instances of this corrosion; in fact, it is this type of corrosion

TABLE 1—Tanks*

DESCRIPTION	SERVICE CONDITION			TANK BOTTOM			TANK SHELL			TANK ROOF			REMARKS
	Contents	Temperature, °F.	Percent Concentration	Material	Fabrication	Life in Years	Material	Fabrication	Life in Years	Material	Fabrication	Life in Years	
Light Oil Agitator	Hydrocarbons, H ₂ SO ₄ Sludge	110	104	Steel	Welded	Repaired in 2 yrs.	Steel	Welded	Repaired in 3 Yrs.	.....	No Roof	....	Carbon steel welds leaked. Probably selective corrosion of welds. Monel overlays on welds leaking after 19 mo. Hastelloy overlays good after 45 mo.
Treating Plant Sludge	H ₂ SO ₄ Sludge	80	100	Steel	Riveted	15	Steel	Riveted	15	Steel	Riveted	15	None.
Acid Storage	H ₂ SO ₄	Atm.	98-99	Steel	Welded	4 to date	Steel	Welded	4 to date	Steel	Welded	4 to date	Slight corrosion where exposed to air.
Turbine Oil Treating Agitator	Hydrocarbons, H ₂ SO ₄ Sludge	105	98	Steel Lead	Riveted	Lead Removed in 13 yrs.	Steel Lead	Riveted	Lead Removed in 13 yrs.	Steel	Riveted	25	Lead became brittle. Riveted seams leaking after 6 yrs. Internal riveted seams covered with 1/4 in. steel strips. External rivets and seams seal welded.
Lube Oil Treating Agitator	Hydrocarbons, H ₂ SO ₄ Sludge	110-130	88-98	Steel	Riveted	26	Steel	Riveted	37	Steel	Riveted	35	Riveted seams subsequently welded. Bottom corrosion rate .017 ipy. Shell corrosion rate .007 ipy.
Treating Acid Storage	H ₂ SO ₄	Atm.	88-98	Steel	Riveted	Un-known	Steel	Riveted	Un-known	.....	No Roof	....	None
Alkylation Contact Acid Settler	Hydrocarbons, H ₂ SO ₄ Sludge	50	88-98	Steel	Welded	Un-known	Steel	Welded	Un-known	.....	No Roof	....	Light pitting on bottom.
Lube Oil Treating Agitator	Hydrocarbons, H ₂ SO ₄ Sludge	115-154	94	Steel Lead	Welded Burning	.....	Steel	Riveted	20	Steel	Welded	5	Uniform corrosion of shell. Roof corrosion from condensed moisture and acid. Riveted seams failed after 1 year. Galvanic action between copper and steel.
Lube Oil Treating Agitator	Hydrocarbons, H ₂ SO ₄ Sludge	140	85-93	Steel	Cu Riveted	1	Steel	Riveted	10	Steel	Riveted	6	Rivets corroded in cone bottoms.
Lube Oil Treating Agitator	Hydrocarbons, H ₂ SO ₄ Sludge	140	85-93	Steel	Welded and Riveted	.....	Steel	Welded and Riveted	10	Steel	Riveted	.....	General thinning. Pits on roof due to fumes and condensation.
Acid Storage	H ₂ SO ₄	Atm.	91	Steel	Welded	5	Steel	Welded	5	Steel	Welded	5	Outside corrosion by weak acid formed by moisture in air and spilled strong acid.
Spent Alkylation Sludge Storage	H ₂ SO ₄ Sludge	Atm.	88-89	Steel	Welded	4 to date	Steel	Welded	4 to date	Steel	Welded	4 to date	Failure at butt welded joints by uniform corrosion of welds.
Spent Alkylation Acid Storage	H ₂ SO ₄	Atm.	88	Steel	Riveted	10	Steel	Welded	10	Steel	Welded	10	Corrosion through shell at liquid level.
Acid Storage	H ₂ SO ₄	110	85	Steel	Welded	8	Steel	Welded	5	Steel	Welded	8	Outside corrosion.
Sludge Storage	H ₂ SO ₄ Sludge	80	65-85	Steel	Riveted	20	Steel	Riveted	20	Steel	Riveted	20	Only minor repairs required. Pits on roof due to condensation.
Sludge Settler	H ₂ SO ₄ Sludge	130	55-85	Steel	Welded and Riveted	10	Steel	Welded and Riveted	10	.....	No Roof	....	Shell steel corroded.
Sludge Storage	H ₂ SO ₄ Sludge	150	84	Steel	Welded	6 to date	Steel	Welded	6 to date	Steel	Welded	6 to date	Lining removed after 2 yrs. Tank placed in strong acid service.
Alkylation and Kerosene Sludge Storage	H ₂ SO ₄ Sludge	Atm.	80-82	Steel	Welded	4 to date	Steel	Welded	4 to date	Steel	Welded	4 to date	Tank became thin throughout by acid corrosion as a result of lining leakage.
Sludge Storage	H ₂ SO ₄ Sludge	.....	77	Steel	Riveted	10-15	Steel	Riveted	10-15	Steel	Riveted	10	Plates and rivets corroded.
Lube Plant Acid Storage	H ₂ SO ₄ Sludge	.....	77	Steel Lead	Riveted Burning	1 1/2-2	Steel Lead	Riveted Burning	1 1/2-2	Steel	Riveted	.....	Corrosion from spillage.
Sludge Tank	H ₂ SO ₄ Sludge	200-250	77	Steel Lead	Riveted Burning	19 1/2-1	Steel Lead	Riveted Burning	19 1/2-1	.....	No Roof	....	None.
Acid Storage	H ₂ SO ₄	.....	77	Steel	Riveted	20	Steel	Riveted	20	Steel	Riveted	20	Lead failure by fatigue.
Alkylation Sludge Storage	H ₂ SO ₄ Sludge	.....	77	Steel	Welded	3 to date	Steel	Welded	3 to date	Steel	Welded	.....	Lead leaks resulted in corrosion of the steel.
Treating Sludge Storage	H ₂ SO ₄ Sludge	150	75	Steel	Welded	3 to date	Steel	Welded	3 to date	.....	No Roof	....	Vapor corrosion of roof.
Sludge Hydrolyzer	H ₂ SO ₄ Sludge	200-220	45-65	Steel Lead Brick	Welded Burning	5	Steel Lead	Welded Strapped	5	.....	No Roof	....	None.
Sludge Hydrolyzer	H ₂ SO ₄ Sludge	200-220	10-90	Steel Lead Brick	Welded Burning	3-6	Steel Lead	Strapped	3-6	.....	No Roof	....	Lead failure by fatigue.
Alkylation and Kerosene Sludge Storage	H ₂ SO ₄ Sludge	60-120	50-89	Steel Lead Brick	Riveted Burning	15	Steel Lead Brick	Riveted Burning	15	Steel	Riveted	12	Lead leaks resulted in corrosion of the steel.
Lube Oil Treating Plant Sludge	H ₂ SO ₄ Sludge	Atm.	45-65	Steel Lead	Riveted	47	Steel Lead	Riveted	47	.....	No Roof	....	Vapor corrosion of roof.
Rundown Tank	H ₂ SO ₄ Sludge	200	60	Steel	Riveted Bolted	25	Steel	Riveted	32	Steel	Riveted	.....	None.
Lube Oil Sludge	H ₂ SO ₄ Sludge	200	60	Steel	Riveted Bolted	8	Steel	Riveted	8	Steel	Riveted	.....	None.
Sludge Separator	H ₂ SO ₄ Sludge	225	50	Steel Lead	Riveted	5	Steel Lead	Riveted	5	Steel Lead	Riveted	5	Caustic used in neutralizing caused hardening of the lead.
Recovered Acid	H ₂ SO ₄	240	48	Steel Lead	Riveted Burning	8-10	Steel Lead	Riveted Burning	15	Steel Lead	Riveted Burning	20	Heat cycles caused cracking of the lead.
Weak Acid Separator Drawoff	H ₂ SO ₄	180	47	Steel Lead	Welded Burning	7	.....	.....	.....	.....	.....	.....	Failure of lead by fatigue.
Rundown Tank	H ₂ SO ₄	0-250	35-40	Steel Lead Brick	Riveted Burning	10-15	Steel Lead	Riveted Burning	10-15	.....	No Roof	....	Failure of lead by fatigue.
Acid Cooking Kettle	H ₂ SO ₄	150	35-40	Steel Lead Brick	Riveted Burning	1 1/2-2	Steel Lead	Riveted Burning	1 1/2-2	Steel	Riveted	10-15	Expansion and contraction held to a minimum by brick.
Acid Oil Tank	Hydrocarbons, H ₂ SO ₄	.....	.....	Steel Lead Brick	Riveted Burning	10-15	Steel Lead	Riveted Burning	10-15	.....	No Roof	....	Mechanical failure of lead.
Sludge Separator	H ₂ SO ₄ Sludge	180-200	30-40	Steel Lead	Bolted	10	Steel Lead	Bolted	10	.....	No Roof	....	None.
Weak Acid Storage from Separators	H ₂ SO ₄	Atm.-220	35-40	Steel Lead	Welded Bolted	5 to date	Steel Lead	Welded Bolted	5 to date	.....	No Roof	....	None.
Sludge Separator	H ₂ SO ₄ Sludge	220	35-40	Steel Lead Brick	Welded Burning	7 to date	Steel Lead	Welded Bonded	.....	Steel Lead	Welded Bonded	.....	Minor repairs to bonded lead in 6 months and minor repairs to steel after 3 yrs.
Acid Storage and Settler	H ₂ SO ₄ , Water	150	10-38	Steel Lead	Welded Burning	12	.....	.....	12	.....	No Roof	....	Breaks in lead and corrosion of steel.
Sludge Fluxing Tank	H ₂ SO ₄ Sludge, Water	200	32	Steel Lead	Riveted Burning	12	Steel Lead	Riveted Burning	12	.....	No Roof	....	Corrosion.
Sludge Fluxing Tank	.....	200	15	Steel Lead	Welded	12	Steel Lead	Welded	12	.....	No Roof	....	Breaks in lead, subsequent corrosion of steel.
Sludge Storage	H ₂ SO ₄ Sludge	200	4-5	Steel Lead	Riveted Burning	15	Steel Lead	Riveted Burning	20	.....	No Roof	....	None.
Neutralization of Nitro-acid Treating	H ₂ SO ₄ Soda Ash	40-120	0.2	Steel	Welded	8-16	Steel	Welded	8-16	Steel	Welded	.....	Greatest corrosion in top half. Inside patches installed.

* API Proceedings, Vol.32M (III) (1952).

TABLE 2—Lines*

DESCRIPTION	SERVICE CONDITION			LINE DATA			REMARKS
	Contents	Temperature °F	Percent Concentration	Material	Fabrication	Life in Years	
Acid Transfer.....	H ₂ SO ₄	110	103	Steel (Sch 80)	Welded	1	Failure at welds.
Acid Transfer.....	H ₂ SO ₄	80	100	Steel	Welded and Screwed	15	None
Acid Transfer.....	H ₂ SO ₄	Atm	98-99	Steel (Sch 40)	Welded	4	General corrosion.
Acid Transfer.....	H ₂ SO ₄	Atm	98	X H Steel	Screwed	10	Corrosion at threads.
Acid Transfer.....	H ₂ SO ₄	Atm	88-98	Steel	Welded	..	None
Sludge Transfer.....	H ₂ SO ₄ Sludge	110-130	88-98	X H Red Brass	Brazed	..	No repairs to date (1 year).
Acid Transfer.....	H ₂ SO ₄	Atm-90	65-98	Steel	Welded and Screwed	..	Failure by underground external corrosion.
Acid Transfer.....	H ₂ SO ₄	100	95	Steel (Sch 80)	Welded	5	Failure at welds.
Acid Transfer.....	H ₂ SO ₄	Atm	93	X H Steel	Screwed	10	Corrosion at threads.
Sludge Transfer.....	H ₂ SO ₄ Sludge	120	90	Red Brass	Welded	3-5	General thinning.
Spent Acid and Sludge.....	H ₂ SO ₄ Sludge	50-70	80-90	Steel	Welded	..	No failure in 6 years.
Agitator to Separator.....	H ₂ SO ₄ Sludge	100	10-90	Steel	Welded and Screwed	2-4	Corrosion at bottom of line.
Alkylation Acid Sludge.....	H ₂ SO ₄ Sludge	Atm	88-89	Steel (Sch 40)	Welded	4	General corrosion.
Alkylation and Kerosene Sludge.....	H ₂ SO ₄ Sludge	60-120	50-89	Steel and Brass	Screwed	10-15	Failure at threads and bends due to moisture in line.
Spent Alkylation Acid.....	Alky. Acid	Atm	88	Steel	Screwed	1	Outside corrosion.
H ₂ SO ₄ Esters and Hydrocarbons.....	Hydrocarbons	100	85	Steel	Welded	7	Corrosion by outside atmosphere and electrolytic action.
Kerosene Sludge.....	H ₂ SO ₄ Sludge	100	85	Steel	Welded	15	Subject to atmospheric corrosion only.
Spent Acid from Treating of Kerosene.....	H ₂ SO ₄	110	85	Steel	Welded	1/4	Excessive velocity (6.5 ft. per sec.).
Acid and Sludge Line.....	Sludge, H ₂ SO ₄	80	65-85	Steel	Welded and Screwed	5	Corrosion at threads.
Alkylation Acid Sludge.....	H ₂ SO ₄ Sludge	150	84	Steel	Welded	5	Corrosion at welds.
Lube Oil Sludge.....	H ₂ SO ₄ Sludge	90-140	60-80	X H Red Brass	Brazed and Screwed	4	Corrosion first occurs at threads.
Acid Transfer.....	H ₂ SO ₄	80-150	62-78	Steel	Welded and Screwed	5	Corrosion at threads.
Strong Acid Line.....	H ₂ SO ₄	60-150	77	Steel (std)	Welded	15-20	Minor repairs.
Strong Acid Line.....	H ₂ SO ₄	250	77	Steel (std)	Welded	..	Corroded through in 6 months.
Sludge from Acid Treated Wax.....	H ₂ SO ₄ Sludge	150	75	Steel	Welded	..	No failure after 1 1/2 years.
Acid Transfer.....	H ₂ SO ₄	60-150	62	Lead	Burning	25	None
Concentrator Acid Feed.....	H ₂ SO ₄	125-150	55	Lead	Soldered	..	No failure after 7 years.
Sludge Transfer Steam Lift.....	H ₂ SO ₄ Sludge	120	49	Steel Lead Lined	..	1 1/4	Erosion of lead by steam.
Occasionally.....	H ₂ SO ₄ Sludge	100	48	Brass	Screwed	10-12	Corrosion of threads.
Sludge Fuel Transfer.....	Sludge Fuel	200	10-45	Red Brass	Screwed	6	General corrosion. Replaced Ni-Resist.
Sludge Line.....	H ₂ SO ₄ Sludge	200-220	10-45	Red Brass	Screwed	6	General corrosion.
Weak Acid at 25 PSI.....	H ₂ SO ₄	60-150	35-40	Lead	Burning	20	None
Weak Acid at 100 PSI.....	H ₂ SO ₄	60-150	35-40	Lead	Burning	1-2	Pressure stretches line.
Weak Acid at 200 PSI.....	H ₂ SO ₄	60-150	35-40	Lead	Burning	1	Pressure stretches line. 1 yr. or less
Sludge Fuel Transfer.....	Sludge Fuel	210	35-40	X S Red Brass	Brazed	10	None
Weak Acid to Storage.....	H ₂ SO ₄	210	35-40	Std. Red Brass	Brazed	11	Mechanical wear and corrosion at joints.
Recycle Weak Acid.....	H ₂ SO ₄	150	10-38	Red Brass	Welded	6	Previously used screwed joints lasted 3 months.
Recovered Acid.....	H ₂ SO ₄	140	37	Lead	..	3	Leaks caused by expansion.
Weak Acid and Caustic.....	Caustic, Acid	70	34	Yellow Brass	..	1	Corrosion by caustic and acid.
Weak Acid Transfer.....	H ₂ SO ₄	180-200	28-30	Red Brass	..	2-3	General thinning.
Lube Oil Sludges.....	H ₂ SO ₄ Sludge	180-200	10-30	X S Red Brass	Brazed and Screwed	4-6	Failure at threads.
Acid Sludge Fuel.....	Sludge Fuel	200-220	5-30	Steel Lead Lined	..	6	Corrosion and erosion.
Lube Oil and Wax Treated Acid.....	H ₂ SO ₄	160	25	Red Brass	Screwed	1/4	Corrosion of threads.
Acid from Cooking Tank.....	Acid and Oil	200	15-20	Red Brass	Welded	1-2	Welds corroded through.
Acid Tar.....	H ₂ SO ₄	180-200	10	Steel (Sch 80)	Welded	4 1/2	Failure at welds.
Acid Oil.....	H ₂ SO ₄ Sludge	200	4-5	Red Brass	Welded	6	Uniform corrosion
Weak Acid Circulating.....	H ₂ SO ₄	175-200	2-5	Haveg	Flanged	..	No sign of corrosion or erosion. 5 1/2 years to date.
Weak Acid Circulating.....	H ₂ SO ₄	175-200	2-5	Karbate	Flanged	..	Seam splitting and flange leakage. 5 1/2 years to date.
Weak Acid Circulating.....	H ₂ SO ₄	175-200	2-5	Lead	..	..	6 to 8 months' life. Erosion and fatigue.

*API Proceedings. Vol. 32M (III) (1952)

which in the past has been responsible for limiting the use of welded steel equipment for acid service in some refineries.

Table 1 indicates that this selective attack of carbon-steel welds was not uncommon. The table shows that one tank which stored 104 percent sulfuric acid began to leak at the welds in a few years; and another, which stored 88 percent sulfuric acid failed by uniform corrosion of the welds. In the piping section (Table 2) many examples of selective corrosion of carbon-steel welds are mentioned. In one refinery, where preferential attack was noted, a series of corrosion tests were conducted. These tests showed that the structure of the metal adjacent to the welds was spheroidized. Although stress relieving did not prevent the corrosive attack, normalizing did. This indicates that residual stresses are not the primary cause of the preferential attack, but rather that the structure of the steel is an important factor in this type of corrosive attack. Research is being conducted on this selective type of corrosion, both in the laboratory and in the field.

It has been reported that corrosion takes place more rapidly in the vapor spaces of acid tanks than below the liquid level. The corrosion probably results from weak acid formed by condensed moisture and acid fumes. Also, when a tank is emptied, the acid film which remains on the tank surfaces unites with moisture from the air to form weak sulfuric acid, which readily corrodes steel.

Liquid-Level Line Corrosion

It has been observed that, when sulfuric acid is stored without a change in the liquid level, severe corrosion may take place on the tank surface at the liquid-level line. The corrosion appears as a deep circumferential groove, and is caused by the absorption of moisture from the air by the acid at the surface. A top layer of weak acid is formed which corrodes the steel. This condition can be alleviated by frequent changes in liquid level. Spills on the roofs or on the sides of tanks also result in weak acid and accelerated corrosion.

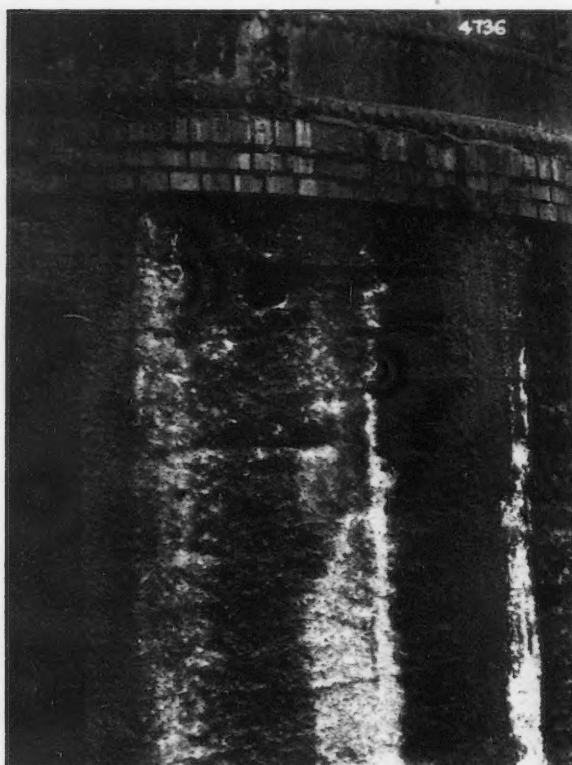


Figure 5—Deterioration of concrete foundation from acid leaks and spills.



Figure 6—Acid attack on concrete foundation which occurred underground.

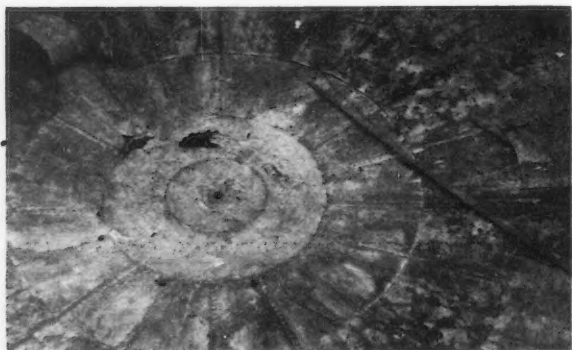


Figure 7—Tank bottom where steel has holed through as a result of breaks in lead lining.

Attack on Concrete Foundations

Acid tanks and treating vessels which handle weak and strong acid are often supported by concrete foundations. Deterioration by sulfuric-acid spills is quite noticeable in the case of the concrete foundation shown in Figure 5. In several instances, this attack necessitated replacement of the foundations. Figure 6 shows the damage which was particularly severe below the ground level where acid had seeped into the ground. This attack is not usually rapid—occurring in 15 to 20 years, or longer. The time is dependent on the amount and frequency of spills and may be shorter or longer. Relative costs determine the type of protection applied; either the foundations may be coated with acid-resistant coatings, or the thickness of the concrete may be increased to take care of the gradual deterioration. If the latter method is used, limestone may be placed adjacent to the portion of the foundation which is underground so as to help neutralize the acid retained in the ground.

Tanks for Weak Sulfuric Acid and Weak Sulfuric-Acid Sludge

The principal material used in the handling of weak sulfuric acid and weak sulfuric-acid sludges is lead. It is also used to handle strong sulfuric acid at temperatures at which steel would show high corrosion rates and for processes which involve both weak and strong sulfuric acid. Lead is applied as a liner to a welded or riveted steel tank. The steel furnishes the strength, and the lead the necessary corrosion resistance.

Strangely enough, the greater part of the corrosion experience with most lead-lined equipment is found not in the lead, but in the steel shell which the lead protects. Generally, at the temperatures and sulfuric-acid concentrations which are associated with refinery operations, lead shows very little loss from corrosion. In fact, failures in the refinery due to actual corrosion of lead by sulfuric acid are not numerous. The high maintenance and corrosion failures associated with lead-lined equipment are the result of physical failures of the lead lining. Once there is a break in a loose lead lining, the acid will seep through the break and attack the steel. Considering the fact that lead-lined equipment in most cases contains weak sulfuric acid, the steel holes-through rapidly.

A typical failure is shown in Figure 7. Weep holes are drilled in steel tanks in an effort to detect the leakage before serious corrosion of the steel results. So it follows that, in discussing corrosion of lead-lined equipment in the refinery, emphasis is placed on the physical failures which occur because they are

TABLE 3—Initial Stress—Sheet Lead Linings

HEIGHT (Feet)	Maximum Initial Stress (PSI)
30.....	160
25.....	133
20.....	107
15.....	80
10.....	53.3
5.....	26.6

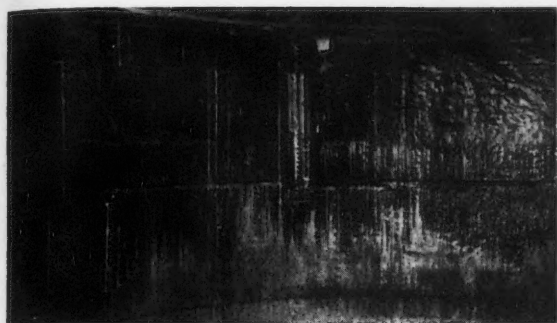


Figure 8—Creep of a loose lead lining.

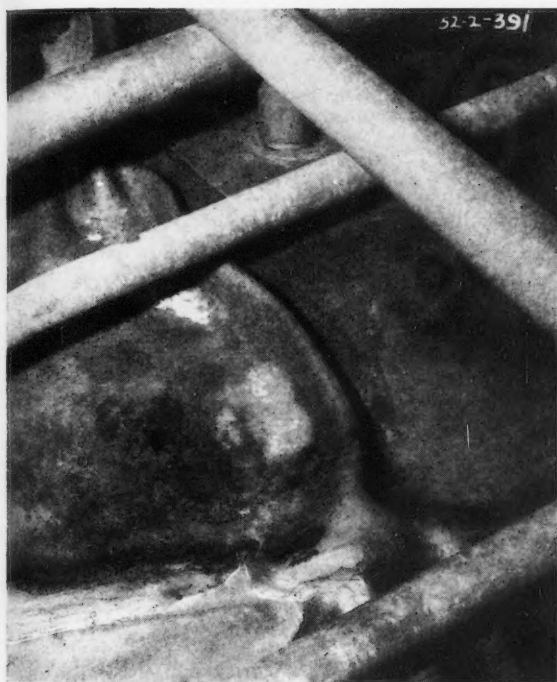


Figure 9—Creep of a loose lead lining. The lead covered the sloping bottom of a tank.

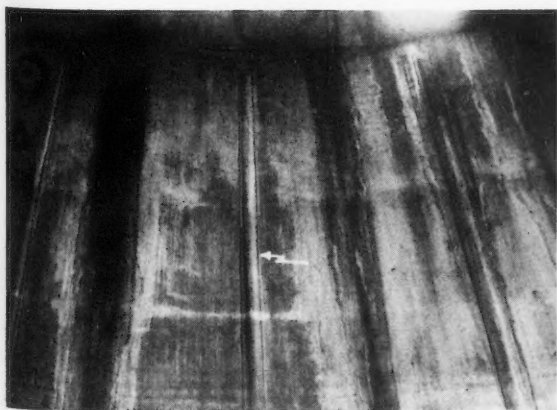


Figure 10—Strapping used to support a loose lead lining.

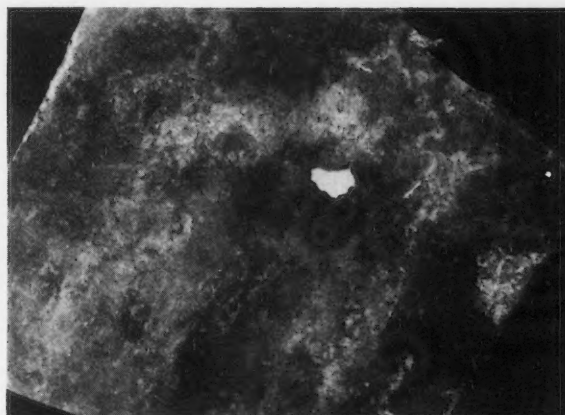


Figure 11—Rupture of lead over a riveted seam.



Figure 12—A lead-lined tank bottom. Brick was used to hold and protect the lead. The center portion of the tank which corroded because of breaks in the lead has been removed.

responsible for the greater part of the corrosion experienced with lead-lined equipment.

Characteristics of Lead Lining

Sheet lead for lining usually comes in rolls ranging from 8 to 12 feet wide. The thickness is designated by weight. Approximately 1 sq. ft. of lead 1/64-inch thick weighs 1 lb. and is called 1-lb. lead. In the refinery 10-lb. lead (5/32-inch thick) and 12-lb. lead (3/16-inch thick) are used quite extensively. The lowest construction cost for a lead-lined steel tank is realized when the sheet lead is hung from the top of the tank shell. However, this is not necessarily the most economical method, because future maintenance may be increased.

It has been reported that the optimum height of a loose lead-lined vessel, without any additional support at points other than where the lead is fastened at the top of the vessel, is 10 feet. Highest stress, due to the weight of the lead lining, is in the upper part of the lining. Table 3 shows the initial stress which is developed in sheet lead linings of different heights. This table is important in that an increase in stress will cause increased creep and probably will produce a higher frequency of failures which, in turn, results

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Maximum Initial Stress (PSI)
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133
107
80
53.3
26.6

in higher maintenance. The stress is not constant, but will increase as the thickness of the lead is reduced through creep.

Sagging of the lining as a result of creep is shown in Figure 8. Excessive creep, such as that depicted in Figures 8 and 9 may cause rupture of the lead. Various means are adopted to compensate for the relatively low strength of lead. One of the most common methods of supporting lead is by strapping. This is accomplished, as shown in Figure 10, with steel straps which secure the lining. The straps are held in place by bolts which pass through the lining and which are fastened to the steel shell. The steel is then covered with strips of lead.

Failures Other Than Creep Failures

Creep and fatigue failures are not the only failures experienced with lead linings. It was noted that, in the case of riveted tanks, failures of the lead lining occurred more frequently at the riveted seams. An investigation disclosed that the pressure of the tank contents stretched the lead over the rivet heads. A section of lead which had been removed from the lining over a riveted seam is shown in Figure 11. The rupture occurred at the rivet head. Inasmuch as lead will assume the same general shape as the steel backing material and, in so doing, may deform to the point of failure, it is desirable to obtain as smooth a steel surface as possible without abrupt changes in shape.

In addition to strapping, a layer of acid brick is sometimes placed over the lead lining on the bottom of the tank or vessel. The main purposes of the brick are to hold the lead in place and to prevent steam from open or ruptured coils from eroding the lead. One disadvantage of this method is that, when a leak does occur in the lead lining, it is often necessary to tear up a large amount of brick work before the leak can be located. The additional work of removing and replacing the brick involves considerable expense. Figure 12 indicates the work involved when a leak occurs in this kind of a bottom. Whether brick is justified will depend on maintenance records.

Construction For Severe Service

Another method of construction often is used if one or more of the following conditions are present:

1. High pressures or vacuum
2. Severe corrosion or erosion
3. High velocities
4. High temperatures

The construction consists of a steel vessel shell lined with lead, sometimes followed by a layer of asbestos and then by one or more layers of acid-proof brick cemented together with acid-proof cement. This method of fabrication is expensive, although it may be cheaper from the standpoint of lower maintenance. Experience with similar construction was observed, except that an organic acid-proof membrane was substituted for the lead. The membrane consisted of several layers of an acid-resistant coating. Failure occurred after two years' service. Investigation disclosed that the brick bottom had heaved upward because of expansion, thus allowing the contents of the

vessel to reach the membrane. The membrane, not able to withstand the temperature, became ineffective as a barrier, with the result that the bottom corroded out. The expansion of the brick bottom was sufficient to cause the steel shell to crack locally. Possibly this construction would have been satisfactory if sufficient expansion joints had been provided.

Bonded lead construction is used to some extent in the refinery for construction of tanks and vessels. Bonded lead consists of a layer of lead applied to steel plate in such a way that an integral bond is produced. Bonded lead has been recommended by some lead-equipment fabricators when one or more of the following factors are involved:

1. High temperatures, which would produce excessive creep in loose lead linings.
2. Fluctuating temperatures, which would make loose lead linings unsuitable because of fatigue.
3. Operation of vessels under vacuum.
4. Conditions where heat transfer is important.
5. Applications where loose linings have resulted in high maintenance costs.

Fatigue Cracking of Bonded Lead

One refinery that was experiencing a high rate of maintenance with loose lead-lined separator tanks thought that bonded lead bottoms might reduce some of this maintenance. A separator which was to be used for the hydrolysis of sludge was constructed with a bonded lead bottom and a loose lead sheet lining for the shell. The bonded lead of the bottom was joined to the loose lead of the shell by burning. After a few months of operation leaks started in the portion of the lead which had been burned to the bonded lead. The tank was repaired and placed in service and it again developed a leak at the joint where the loose lead joined the bonded lead of the bottom. A joint using a strap, as shown in Figure 13, was adopted to prevent failures. Later an examination of the bonded lead bottom showed many small cracks, as pictured in Figure 14. Some of these were chipped out and found to extend to the steel bottom. It was believed that the cracks were caused either by stress imposed in the lead during heating and cooling cycles which resulted from batch processing, or by inferior lead. Laboratory experiments involving tem-

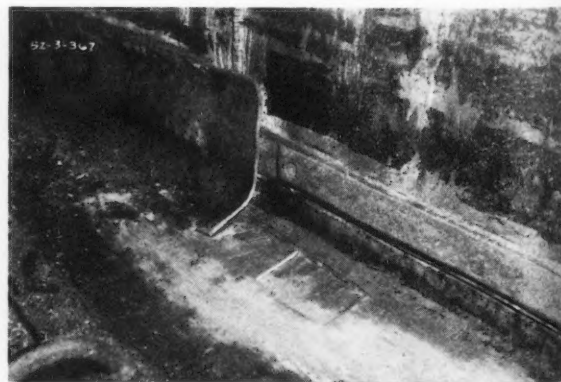


Figure 13—Strapping of a circumferential seam. The seam was formed by burning the loose lead lining of the shell to the lead-bonded bottom.

perature cycling were made upon lead-bonded steel plates which duplicated the cracking found in the tank bottom. Figure 14a shows the fatigue cracks produced in the lead layer by cycling between 270 and 70 degrees F. Figure 14b, a cross section view of the lead layer, shows the extent of crack penetration below the surface. Tellurium lead was found to have considerably greater resistance to fatigue cracking than chemical lead.

Lines for Strong Sulfuric Acid and Strong Sulfuric Acid Sludges

Lines which operate at moderate temperatures and handle strong acid and acid sludge are generally fabricated from carbon steel, provided steam is not injected into the lines. Steam would result in weak acid and excessive corrosion. The necessity for placing a temperature limit on the use of steel is evidenced by a line reported in Table 2 which had a life of only six months. The line transported 77 percent sulfuric acid at 250 degrees F.

Screwed Lines Are Troublesome

Both screwed and welded carbon-steel lines are employed in strong sulfuric-acid-sludge service. Experience has shown that screwed lines are very troublesome because of corrosion of the threads and resultant leakage of acid. Moreover, the leaking acid unites with the moisture from the air, thus giving weak acid which accelerates corrosion from the outside of the pipe as well. Repairs are difficult to make, but sometimes attempts are made to seal-weld the screwed fittings. However, in most instances it is necessary to scrap the installation and install new lines.

Welded construction would appear to be the solution to the difficulties encountered with threads. However, the selective corrosion of the carbon steel welds described previously also occurs in pipe welds. If both methods of fabrication are considered, welded carbon steel pipe definitely appears to be the lesser of two evils for the reason that, if selective corrosion of the welds results in leaking, it is possible to chip and reweld; whereas with screwed lines, repairs usually are not economical. The survey on lines (Table 2) showed that most of the lines which handled strong acid and strong acid sludges were welded.

Brass lines (usually red-brass) are used for strong acid-sludge service in cases where the sludge is very viscous because steam is required for warming and blowing out the lines. Brass lines are desirable because of their resistance to the weak acid formed during steaming operations.

Lines for Weak Sulfuric Acid and Weak Sulfuric-Acid Sludges

Red-brass and lead lines are commonly used to handle weak acid and sludges which contain weak acid. Most of the failures which occur with brass piping are similar to those just mentioned, viz., selective corrosion of threads and welds. The pipe also fails by general corrosion of the pipe wall. Although this depends on the experience of the user, in general welded pipe is preferred to screwed. Table 2 mentions screwed piping used for weak acid (10 to 38 percent) at a temperature of 150 degrees F, which



Figure 14—Cracks which developed in the lead layer of a lead-bonded tank bottom. The tank had been in service about six months.



Figure 14a—Failure of chemical lead in laboratory experiment.

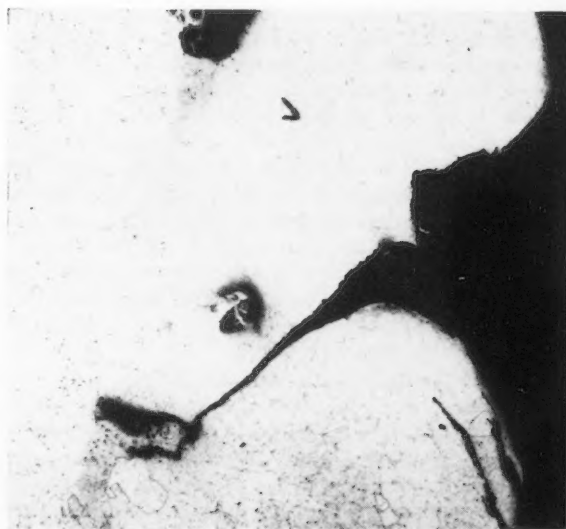


Figure 14b—Cross-section of defect showing extent of crack.

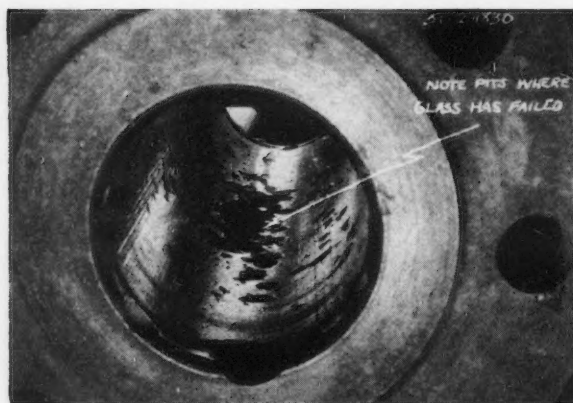


Figure 15—Failure of glass-lined steel pipe in sludge service.

failed in three months because of corrosion at the threads. In another instance screwed red-brass lines failed at the threads in 60 to 90 days, while welded red-brass piping in this same service had a life of six years. Although one instance is reported in Table 2, of a welded brass line which corroded at the welds in one to two years, a survey disclosed that welded brass lines in various acid and sludge services lasted from three to 11 years. In many refineries high maintenance costs associated with the use of threaded connections in acid service have led to these connections being held to an absolute minimum.

Lead Used at Low Pressures

Lead is used for handling acids of various strengths, particularly at low pressures. Because of the physical weakness of lead, most failures occur by rupture and wear. E. L. Hildebrand¹ mentions experience with lead-bonded steel pipe which required maintenance in less than a year of service with 10 leaks occurring in one 100-foot section of 6-inch pipe.

He refers to another line which was used in transferring sludge from the sludge kettles to the boiler house. This line handled sludge at a maximum pressure of 375 psi. The acidity varied from 0 to 55 percent sulfuric acid. Extra heavy red-brass pipe had a useful life of approximately five years. A 500-foot length of bonded lead-lined pipe was tried in this line, but the results were very unfavorable. Circumferential cracks developed in the lead adjacent to the flanges and collapse of the lead lining occurred at several points. Repairs were required after only two months, and complete replacement was necessary in less than a year. Failure of the lead was believed to be due in part to the high sludge temperature and in part to the use of 145-lb. steam for clearing the line after each pumping.

Another method of using bonded lead, which reportedly has been successful although initially expensive, is one in which Karbate sleeves are inserted into the lead-bonded pipe. This type of construction was used in the isobutylene extraction units of a butyl-rubber plant which handled 45 percent sulfuric acid at temperatures of 300 degrees F because bonded lead pipe had a life of six weeks. The Kar-

bate serves to reduce the temperature of the lead, it prevents erosion of the lead and it holds the lead in place.

Shock Damages Glass-Lined Pipe

A test was made of glass-lined steel pipe. The line carried sulfuric acid of 28 percent concentration at a temperature of 200 degrees F. At intervals the line was blown out with steam. An inspection after a few month's service showed that the glass had failed and that the pipe was deeply pitted, as shown in Figure 15. It is believed that the failure of the glass-lined pipe may have been the result of the thermal shock produced by the steaming operation.

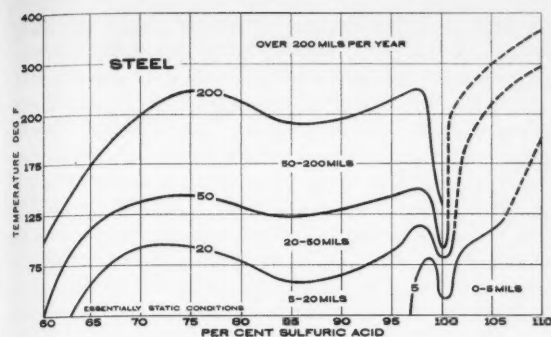
In addition to the materials mentioned, Table 2 shows that Haveg (phenol resin) and Karbate (carbon) pipe have been used to a limited extent in refinery work.

Valves for Strong Sulfuric Acid and Strong Sulfuric-Acid Sludges

One of the most difficult problems in the handling of strong sulfuric acid and strong acid sludges is concerned with the finding of a valve which will perform satisfactorily and safely with the least cost to the user. The reason for the problem is that, although a tank or line can suffer considerable metal loss before it becomes unfit for service, the design of a valve is such that only a small amount of corrosion of the valve gate and seat will result in leakage. One valve manufacturer's experience indicates that the material from which the valve is fabricated should have a corrosion rate less than approximately 0.005-inch per year in order to provide satisfactory valve life. In acid service such a material is not easy to obtain.

Throughout the industry the general practice has been to use carbon steel or cast-iron valves in strong acid service. In the past these valves have been used extensively in acid manufacturing, acid treating of petroleum products and acid-reclaiming processes. Probably the wide use of carbon steel valves stems from the popular belief that strong sulfuric acid is not corrosive to plain carbon steel. Of course, this is a fallacy; for corrosion tests have shown, for example, that 85 percent sulfuric acid at 200 degrees F will corrode carbon steel at the rate of approximately 0.20-inch per year. Reference to Figure 16 shows that strong acid at 100 degrees F will corrode carbon steel at a rate of about 0.021-inch per year and at 150 degrees F approximately 0.05-inch per year. These latter two rates may be permissible on equipment such as tanks and lines where adequate corrosion allowances are provided. Such rates, however, would result in corrosion of valve gates and seats to the extent that faulty valve performance would occur in a relatively short period of time.

In discussing the corrosivity of sulfuric acid with respect to carbon steel, the type of equipment must be considered. This is the reason that, even though the corrosion rate under one set of conditions may be the same for the various kinds of plain carbon steel equipment the effective life of the equipment may vary considerably. In one instance strong acid may

Figure 16—Corrosion of steel by sulfuric acid.²

be considered highly corrosive to carbon steel equipment because even low corrosion rates result in a short service life; in another instance, the same corrosion rate with respect to other carbon steel equipment may not affect the life of the equipment materially and, although all conditions are the same, no corrosion problem exists. Considering that valves depend on low corrosion and erosion rates for satisfactory performance, the trend in strong sulfuric acid and strong acid-sludge service is toward the use of alloy valves which are considerably more corrosion resistant than carbon steel.

Service experience of one refinery with carbon steel valves in strong acid service indicated that the valves failed in periods ranging from two to 18 months, and that average life was six months. Where high veloc-



Figure 17—Corrosion of a carbon steel valve and valve stem which necessitated insertion of a threaded rod to facilitate opening of the valve.

ities were encountered, carbon steel valves were scrapped after only six to eight weeks' service.

It was observed that one of the most common failures of carbon steel valves associated with strong acid was actually the result of corrosion by weak sulfuric acid. The failures occurred in the following manner: The concentrated acid which had remained

TABLE 4—Valves*

DESCRIPTION	SERVICE CONDITION			Type of Valve	STEM		BODY		GATE		SEAT		PACKING		REMARKS
	Contents	Temperature °F.	Percent Concentration		Material	Life in Years	Material	Life in Years	Material	Life in Years	Material	Life in Years	Material	Life in Years	
Concentrated Acid Line	H ₂ SO ₄	80	100	Gate	Steel	2	Steel	2	Steel	2	.....	..	.....	..	Severe corrosion of gate and stem.
Transfer Line.....	H ₂ SO ₄	Atm.	98-99	Cock	Iron	1	Iron	1	Iron	1	Iron	1	Grease	..	General corrosion and wear.
Transfer Line.....	H ₂ SO ₄	Atm.	98	Gate	Steel	..	Iron	..	Mall. Iron	1/2	Integral	1/2	.....	..	Scrapped in 2 months because of seat and gate failure.
Lube Oil Sludge....	H ₂ SO ₄ Sludge	110-130	88-98	Gate	Monel	3	Monel	3	Monel	3	Monel	1	Rubber	1	No appreciable corrosion on body or stem. Seats repaired each year.
Transfer Line.....	H ₂ SO ₄	80-150	90	Plug	Lead Covered Bronze Iron	1 1/2-1	Steel	..	Lead or Rubber	1-2	Lead Covered Bronze Iron	..	.....	..	Bronze corrodes.
Spent Alkylation Acid and Sludge	H ₂ SO ₄ Sludge	Atm.	88-89	Cock	Iron	1	Iron	1	Iron	1	Iron	1	Grease	..	General corrosion and wear.
H ₂ SO ₄ Esters and Hydrocarbons.....	Hydrocarbons	100	85	Gate	Alloy 20	5	Alloy 20	5	Alloy 20	5	Alloy 20	5	Teflon	5	The Alloy 20 valve replaced a steel valve.
Kerosene Sludge.....	H ₂ SO ₄ Sludge	100	85	Gate	Steel	1	Steel	3	Steel	2	Steel	2	Rubber	1/2	None.
Kerosene Sludge.....	H ₂ SO ₄ Sludge	110	85	Gate	Alloy 20	..	Alloy 20	..	Alloy 20	..	Alloy 20	..	Teflon	..	No failure after 3 years.
Sludges from Alkylation	H ₂ SO ₄ Sludge	150	84	Gate	Alloy 20	6	Alloy 20	6	Alloy 20	6	Alloy 20	6	Teflon	6	Teflon replaced asbestos packing.
Acid Transfer Line.....	H ₂ SO ₄	60-150	77	Gate	Steel	2	Iron	2	Iron	2	Steel	2	Rubber	1 1/2-1	None.
Agitator Valve.....	H ₂ SO ₄ Sludge	90	65-75	Gate	Alloy 20	..	Alloy 20	..	Alloy 20	..	Alloy 20	..	Teflon	..	The Alloy 20 valve replaced an iron valve that had 6 weeks' life.
Acid Sludge.....	H ₂ SO ₄ Sludge	80-100	45-65	Cock	Gate	..	Iron	10	Iron	10	Alloy 20	..	Teflon	..	None.
Lube Oil Sludge.....	H ₂ SO ₄ Sludge	200	60	Gate	Alloy 20	..	Alloy 20	..	Alloy 20	..	Alloy 20	..	Teflon	..	None.
Agitator Valve.....	H ₂ SO ₄ Sludge	120	50	Cock	.....	..	Alloy 20	1	.....	..	.....	..	.....	..	Honey combed through body. 1/2 in. deep pits in 6 months.
Treated Sludge and acid.....	H ₂ SO ₄ Sludge	220	35-40	Gate	Monel	..	Monel	6	Monel	..	Monel	2	Rubber	1	No appreciable corrosion of body after 6 years.
Weak Acid Valve....	H ₂ SO ₄	60-150	35-40	Gate	Lead Covered Brass	10	Lead	10	Lead	10	Lead	10	Rubber	1 1/2-1	None.
Cooking Kettles.....	H ₂ SO ₄ Water	200	10-37	Plug	Lead	1-2	Lead	3-5	Lead	1-2	Lead	1-2	Rubber	1/2	Erosion of lead.
Sludge Transfer.....	H ₂ SO ₄ Sludge	200	25-30	Gate	Alloy 20	..	Alloy 20	1	Alloy 20	1	Alloy 20	1	Teflon	..	Intergranular cracking of body.
Acid Sludge Line....	H ₂ SO ₄ Sludge	100-200	10-90	Gate	Bronze	1-5	Bronze	1-5	Bronze	1-5	Bronze	1-5	Rubber	1-5	Corrosion and wear of seats and gates.
Weak Acid Sludge.....	H ₂ SO ₄ Sludge	180-200	10-30	Gate	Bronze	2	Bronze	2	Bronze	1	Bronze	1	Asbestos	1 1/2	Erosion and corrosion.
Acid Oil Draw Lines.....	H ₂ SO ₄ , Oil	200	15-20	Gate	Brass	1 1/2	Brass	3	Brass	1 1/2	Brass	1 1/2	Rubber	1 1/2	Erosion and corrosion.
Sludge Transfer.....	H ₂ SO ₄ Sludge	200	4-5	Gate	Alloy 20	3/4	Alloy 20	2	Alloy 20	3/4	Alloy 20	3/4	Rubber	3/2	General corrosion.

* API Proceedings. Vol.32M (III) (1952).

on the stem when the valve was opened picked up moisture from the air. The diluted acid attacked the stem, thus resulting in a roughened surface. Once the smoothness of the stem surface had been destroyed, leakage of acid could not be stopped. Figure 17 depicts the severity of this external corrosion, which is commonly referred to as sulfating. In this case the stem corroded off, thus necessitating the insertion of a threaded steel rod before the valve could be operated. The valve was removed as soon as operations permitted.

Alloy Solves Valve Problem

A valve made from an alloy designated in this paper as Alloy 20 was found to be the solution to this maintenance problem. A four-year life to date has been obtained with valves manufactured from this alloy and a longer life is expected. Table 4 shows service lives as long as six years. In the wrought form, Alloy 20 is called Carpenter 20. The cast alloy is made by a number of foundries which use their own trade names such as Aloyco 20, Durimet 20, FA-20 and others. For purposes of simplicity, the alloy is referred to in this paper as Alloy 20. All component parts of the valve are made of Alloy 20, which has the following composition: chromium, 19 to 21 percent; nickel, 28 to 30 percent; copper, 3.6 to 4.5 percent; molybdenum, 2.0 to 3.0 percent; silicon, 1.0 to 1.5 percent; maximum carbon, 0.07 percent; iron constituting the balance.

Alloy 20 is a balanced composition, with a high order of erosion and corrosion resistance to a wide range of sulfuric-acid concentrations. In addition, Alloy 20 valves packed with Teflon, which is completely inert to sulfuric acid, have virtually eliminated packing maintenance. Teflon is the trade name for the plastic material, polytetrafluorethylene. In connection with sulfuric-acid equipment, Teflon is one of the major contributions in the materials field. Previous to the introduction of Teflon, no entirely suitable packing material was available and in some cases valves were regularly repacked in periods as short as two weeks. A large amount of money was expended as a result of the excessive packing maintenance associated with acid and acid sludges.

TABLE 5—Strong Sulfuric-Acid Service
(Average cost per valve location)

SIZE (Inches)	COST PER YEAR USING			Savings Per Year
	Type	Carbon Steel Valves	Alloy-20 Valves	
2.....	Gate	\$170	\$26	\$144
3.....	Gate	200	37	163
4.....	Gate	258	52	206

TABLE 6—Strong Sulfuric-Acid Sludge Service
(Average cost per valve location)

SIZE (Inches)	COST PER YEAR USING			Savings Per Year
	Type	Carbon Steel Valves	Alloy-20 Valves	
1.....	Gate	\$ 61	\$23	\$38
2.....	Gate	101	36	65
3.....	Gate	122	53	69
4.....	Gate	165	75	90

A study of one refinery revealed that packing maintenance on a 3-inch valve in sludge service amounted to \$75 per year for labor and materials. Except for occasional tightening of the gland bolts, Teflon has eliminated packing maintenance for the life of the valve. When hundreds of valves are involved, the savings from this item alone are substantial. The Alloy 20 valve packed with Teflon is also being used in handling sludges which contain strong sulfuric acid and have proved equally effective in sludge service, provided moderate temperatures were involved. A few premature failures have occurred with Alloy 20 valve bodies in strong acid-sludge service but in all cases the valves had been insulated so that, in steaming operations, the temperature exceeded to a considerable degree the upper limit of 150 degrees F. An example of the costs involved in using carbon steel and Alloy 20 valves is given in Tables 5 and 6. The figures include labor and repacking charges and were taken from data obtained in a refinery.

The superiority of the Alloy 20 valves over carbon steel valves led to the standardization of Alloy 20 in one refinery for all valves in services which involve strong sulfuric acid and strong sulfuric-acid sludges at temperatures under 150 degrees F. It has been estimated that the standardization is resulting in annual savings of more than \$75,000.

Valves in Weak Sulfuric Acid and Weak Sulfuric-Acid Sludge Service

It has been implied, when discussing sludges which contain strong acid, that the corrosion characteristics of a sludge are similar to those which would be expected from the concentration of the acid present in the sludge. However, other than the apparent fact that the group of materials suitable for handling weak acid is the same group which finds application in handling weak acid sludges, no definite correlations can be made between materials and the acid concentration in the sludge. This is borne out by experience and by reports that weak acid sludges in some refineries are far more corrosive than similar sludges in other refineries. The reason for the differences is not obvious, although it is known that velocity, temperature and percentages of other constituents vary widely among refineries.

For example, sulfonic acid which is present in some sludges may increase corrosion, whereas other compounds may be present which inhibit corrosion. These differences make it extremely difficult to recommend materials unless data first have been obtained from corrosion tests. Probably the most severe valve service encountered is in the acid-reclaiming departments, especially when the acid is separated from the sludges by hydrolysis. In this operation sludge is mixed either with water or with oil and weak acid. The mixture is heated and agitated with open steam coils and finally is allowed to settle. The acid layer is drawn off and sent to the concentrating plant and the remaining sludge layer is used for boiler fuel. In this process temperatures in the range of 200 to 250 degrees F are attained.

Higher temperatures, which are probably respon-

sible for high corrosion rates, result from the practice of steaming out the lines before and after the acid sludge is pumped to the storage tanks. This is necessary to keep the sludge fluid during transfer and to free the line of sludge after pumping. It is done with 100-lb. steam so that a temperature of 340 degrees F can be reached in the line. Figure 18 shows the acid attack on the gate of an Alloy 20 valve in this service. It is interesting to observe that even though the gate of the valve had been badly attacked, only minor corrosion of the body was noted. It is believed that the reason for this difference is that the body dissipates its heat to the atmosphere, whereas the gate cannot do so.

Therefore, it is possible in steaming operations for the gate to reach a temperature which approaches that of the steam. At the steam temperature, acid—particularly acid sludge which clings to the gate of the valve—will cause high corrosion rates and short valve life. Overlooking practices such as the use of steam in warming and clearing lines may result in misleading corrosion test data. If the test specimens are placed in the separator or sludge kettle, the high temperatures which result from the steam in the lines will not be obtained. In a study of valve corrosion representative rates can be had only by placing the specimens in the lines. Such an assembly is shown in Figure 19.

In services where sludge is hydrolyzed valves have a relatively short service life for the reasons just stated. Because of the extreme conditions of temperature and the wide range of acid concentrations, the average service life of the presently used Alloy 20 valve is six months. Service lives as short as two weeks have been reported. It is understood that Alloy 20 is not designed for such extreme conditions but it has proved to be an easily operated valve. Although the testing program is incomplete, it is believed to be the most economical valve used to date.

Tests Made to Find Suitable Material

Extensive corrosion tests were prompted by the need for a suitable valve. A test was conducted by inserting into a 4-inch line which carries the sludge and acid from the separators or sludge kettles, a test rod with 10 different alloys attached. The results are given in Table 7. The test disclosed that Alloy N-2 (similar to Hastelloy B) and Duriron were the only alloys which showed satisfactory resistance. Unfortunately both of these alloys present problems when they are used for the construction of valves.

The high-silicon iron known as Duriron, has excellent corrosion and wear resistance. However, it is susceptible to failure from the thermal shock encountered in the refinery. To minimize this physical weakness, an experimental 4-inch, Y-type valve was procured by one refinery which consisted of an aluminum-bronze body with Duriron seat and plug. The valve has proved to be satisfactorily resistant to corrosion and no particular hazard exists, because the bronze body of the valve is capable of withstanding thermal shock.

Hastelloy B, although it possesses the necessary physical properties, is expensive compared to some

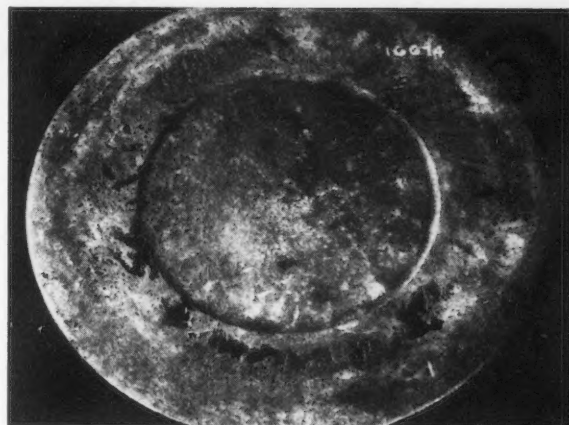


Figure 18—Severity of corrosion which can occur in weak acid-sludge service. Showing Alloy 20 valve gate.

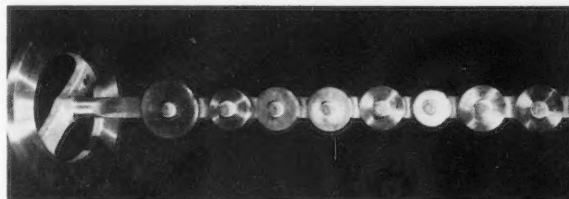


Figure 19—Test assembly used in lines for obtaining corrosion rate data.

TABLE 7—Sulfuric-Acid Sludge and Sulfuric Acid

Majority of exposure, percent sulfuric acid.....	30 to 60
Occasional low, percent sulfuric acid.....	10
Occasional high, percent sulfuric acid.....	98
Temperature, deg F.....	150 to 250

ALLOY	Corrosion Rate (Inches Per Year)
Alloyco 20.....	0.0486
Alloyco 37.....	0.0449
Alloyco N-2*.....	0.0083
Alloyco N-3.....	0.0345
Worthite.....	0.0374
Alloyco 35.....	0.0296
Ampco 8.....	0.0216
Duriron.....	0.0048
Monel.....	0.0304
Hastelloy D.....	0.0351

* Similar to Hastelloy B

of the other commonly used alloys. However, despite the high initial cost of a Hastelloy B valve, it may prove to be economical for the service.

Many Valves Are Being Tested

Valves which have been or are being tested in this service include brass, aluminum-bronze, lead-bonded steel with Monel or Hastelloy B gates, Worthite, Alloy 20, Alloy 37, aluminum-bronze body with Duriron trim, Hastelloy B, and brass body with Hastelloy B trim. The average service life (in months) of those valves which have been tested is as follows: brass—9, aluminum-bronze—8, lead bonded steel (Hastelloy B gate)—18, Alloy 20—6, and Hastelloy B—18. The aluminum-bronze bodied valve with Duriron trim showed no signs of corrosion after 7 months. Because this valve is fabricated in a Y-type design, it is sometimes difficult to use in existing piping systems.

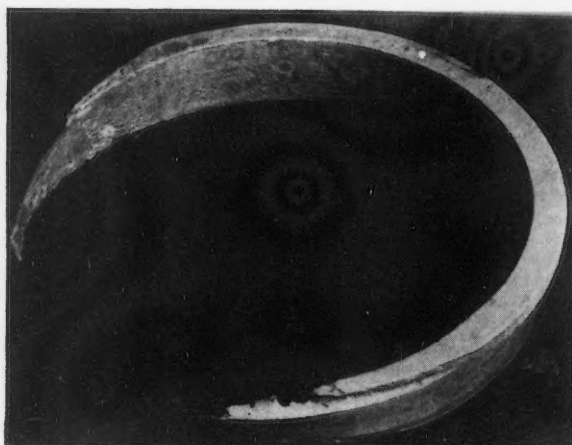


Figure 20—Carbon steel pump valve seat which corroded because of the dilution of strong acid.

Alloy 37 Proves Satisfactory

In another part of the refinery, valves are in service in lines which carry sludge with a sulfuric acid concentration of about 30 percent and a temperature of from 170 to 200 degrees F. A soap which contains 10 to 20 percent sulfuric acid is also pumped through these lines. The lines are steamed. Originally brass valves similar in composition to valves made of 85 percent copper, 5 percent tin, 5 percent zinc, and 5 percent lead provided an average service life of about six months—with three months as the minimum. The valves were changed to Alloy 20, which gave an average service life of approximately one year. In the testing which led to the adoption of Alloy 20 valves, it was discovered that the alloy, as furnished by various manufacturers, differed considerably with regard to corrosion resistance. Subsequent testing disclosed that a modification of Alloy 20, designated as Alloy 37, gave a corrosion rate which was about one-tenth that of Alloy 20.

The analysis of Alloy 37 is given in Table 8. It is interesting to note that only a slight variation of the percentages of the principal elements was required to produce this alloy (Alloy 37), which has a corrosion resistance 10 times that of Alloy 20. However, this advantage did not appear in all tests. In some sludges, Alloy 37 was no better than Alloy 20. Sev-

eral Alloy 37 valves are being tested. Valves of Ampco 8, an aluminum-bronze material, had a service life of 14 months. An Alloy 20 valve with a baked phenolic coating was tested, but the coating failed because of the high temperatures involved. Evaluation of valves in this service has not been completed. Eventually only one type of valve will be used in this service.

The sludge from the acid-reclaiming operations, which is used for fuel, is pumped to storage tanks where it is heated to temperatures around 250 degrees F before it is burned. About 5 percent of the sludge is sulfuric acid. The concentration of the acid in the sludge varies from 20 to 50 percent. Because of the high temperatures involved, all-brass valves have had relatively short lives. The most satisfactory valve thus far found is a Monel-trimmed brass gate valve. To date this valve has given a year's service. Brass valves with Hastelloy B trim are being tested.

No definite recommendations can be given on the particular valve which should be used for each service, inasmuch as testing of valves by the user is required before the most economical valve can be obtained. A valve which is selected for one refinery may not be the best valve for another refinery. However, the valves described, as well as those mentioned in Table 4 should provide a basis for making tests.

One refinery reports that all valves in weak sulfuric acid and weak acid sludge are packed with Teflon, with the result that packing maintenance has been practically eliminated for the life of the valve.

Pumps

Both reciprocating and centrifugal pumps are used to transport acid and acid sludges. Generally when the material being pumped is sufficiently fluid centrifugal pumps are used. For viscous materials such as sludges reciprocating pumps are required.

Heavy sludges which contain strong sulfuric acid are handled with carbon steel or brass reciprocating pumps. Carbon steel is permissible only when strong acid is used in the treating operations and when shut-off valves downstream from the pumps prevent the steam used in clearing the sludge lines from entering the pumps. Steam would dilute the strong acid which remains on the surface of the pump possibly causing corrosion such as that shown in Figure 20. In one case a carbon steel pump which was used for pumping strong acid sludge was steamed out after each pumping. The steam resulted in weak acid corrosion severe enough to warrant scrapping of the entire liquid end. If the introduction of steam cannot be avoided, copper-base alloys are necessary. Table 9 shows that most pumps used in handling sludges, regardless of acid concentration, are made from copper alloys.

Problems Encountered With Reciprocating Pumps

One problem encountered with reciprocating pumps was concerned

TABLE 8

ALLOY	PERCENT NOMINAL COMPOSITION										
	C	Cr	Ni	Mo	Cu	Mn	Si	Fe	Al	Zn	Pb
Aloyco 20.....	.07	20.0	29.0	2.50	4.00	.75	1.00	Bal.	....	....	....
Aloyco 33.....	.07	20.0	36.0	10.00	4.00	.75	1.00	Bal.	....	....	....
Aloyco 35.....	.07	25.0	20.0	3.00	2.75	.75	1.00	Bal.	....	....	....
Aloyco 37.....	.07	25.0	20.0	3.00	2.75	.75	3.00	Bal.	....	....	....
Alpco 8.....	....	....	....	....	89.00	....	....	3.00	8.0	....	....
Alpco 18.....	....	....	....	....	86.00	....	....	3.00	11.0	....	....
Chemical Lead.....	....	....	....	....	....	....	....	....	....	99.9	....
Cupro Nickel.....	....	....	30.0	....	70.00	....	....	....	....	....	....
Durimet T.....	.07	19.0	22.0	2.50	1.00	.65	1.00	Bal.	....	....	....
Durimet.....	.85	....	....	....	....	.65	14.50	Bal.	....	....	....
Aloyco N-2*.....	.07	....	64.0	28.00	....	.65	1.00	6.00	....	....	....
Aloyco N-3*.....	.07	17.0	55.0	17.0	.10	.65	1.00	Bal.	+W4.5	....	....
Hastelloy D.....	.10	....	85.0	....	3.00	....	10.00	Bal.	....	....	....
Monel.....	.10	....	67.0	....	30.00	.75	1.25	1.50	....	....	....
Red Brass.....	....	....	....	....	85.00	....	....	....	....	15.0	....
Stainless 309.....	.10	25.0	10.0	....	....	1.50	.50	Bal.	....	....	....
Worthite.....	.07	20.0	22.0	2.50	1.00	.75	3.50	Bal.	....	....	....

* Aloyco N-2 and Aloyco N-3 are similar to Hastelloy B and Hastelloy C, respectively.

with packing and piston rods. In pumps which handle a heavy sludge which contains 95 percent sulfuric acid, several types of packing were tried—including rubber, blue African asbestos and a special plastic packing. None of these packings was effective in stopping leakage. Regardless of how frequently the packing gland was tightened, the sludge leaked past the packing, thus necessitating in some pumps repacking approximately every week. In addition, a large amount of labor was required to clean up the leakage.

To solve this problem, experiments were conducted using Teflon as a packing material. Solid rings were used first, but were discarded because they could not be compressed sufficiently. Later Teflon in the shape of a V (chevron-type) was installed. This type of packing requires male-and-female adapters which can be procured in Teflon. Only six rings of Teflon were installed in the early tests but more recent evidence indicates that nine rings are more satisfactory. The pumps in which nine rings of packing were used are operating without leakage. Pumps in which six rings were used are operating with a slight amount of leakage.

To date pumps packed with Teflon have been operating for 18 months, without any packing maintenance other than tightening of the gland. In order for packing to be effective, the surface of the pump rod which passes through the packing must remain smooth. Rods which have been used in carbon steel pumps handling strong acid and strong acid sludges were made of carbon steel, of 12 percent chromium-alloy steel or of Type 304 stainless. These materials were probably selected because of their satisfactory resistance to strong sulfuric acid. However, the strong acid which adhered to the rods united with moisture in the air to form weak sulfuric acid which was corrosive to the extent that rods were replaced in four to six months. A pump rod which would be resistant to both weak and strong sulfuric acid, as well as to wear, was required. This dual requirement of corrosion and wear resistance is important because a rod with excellent corrosion resistance would be of little value if it wore and scored easily.

Two materials were found, by test, to be satisfactory for most of the acid and sludge handled in one refinery. These materials are K-Monel and Hastelloy B. K-Monel, as purchased for these rods, has a hardness of 300 Brinell and it is suitable for most applications. Tests have indicated that it is satisfactory for all concentrations of sulfuric acid up to 95 percent if the temperature is not above 150 degrees F. The rods are equally satisfactory for sludges which contain sulfuric acid of strengths up to 95 percent if the temperature does not exceed 150 degrees F. When the concentration of the acid being pumped is under 75 percent or when the concentration of the acid in the sludge is less than 75 percent, K-Monel has been used successfully at temperatures as high as 200 degrees F. For sulfuric acid of concentrations higher than 75 percent and for acid sludges which contain sulfuric acid of strengths in excess of 75 percent, Hastelloy B has given satisfactory service at temperatures above 150 degrees F. To date Hastelloy

B and K-Monel rods have given two years' service life and are still in use.

Limits Based on Field Tests

These temperature and concentration limits have been arrived at by field tests and are approximate; therefore, it is probable that K-Monel can be used outside the limits described. Tests could be run to determine this. Hastelloy B could be specified wherever K-Monel is recommended. However, K-Monel is the cheaper material and is the more economical for the low-temperature services.

Data, although not complete, indicate that Carpenter 20 alloy rods are the most suitable for use in conjunction with 100 to 104 percent sulfuric acid.

Check on Savings Is Made

To determine the savings which could be derived from the use of Teflon packing and suitable pump rods, a group of nine carbon steel pumps was studied. These pumps were used in treating service where they pumped a sludge with a sulfuric acid concentration of about 95 percent, at temperatures below 150 degrees F. When packed with ordinary packings such as asbestos, the pumps required repacking weekly. The 12 percent chromium-steel rods had a life of four to six months. The use of K-Monel rods and Teflon packing in place of the old packings and rods has resulted to date in a rod life of about two years and a packing life of 18 months. Cost records which were kept indicate that on 9 pumps a yearly saving of \$6500 is being realized.

Lead Undesirable in Bronze Pumps

Bronze pumps are commonly used to handle weak acid and weak acid sludges. Bronze also finds considerable use as a pump material for strong acid sludges. Various copper-base alloys, such as those with a composition of 80 percent copper, 10 percent tin and 10 percent lead, as well as those with a composition of 85 percent copper, 5 percent zinc, 5 percent tin and 5 percent lead, have been used for pumps in the past. The addition of lead is believed by some to impart added corrosion resistance. This is not correct, for it has been reported that galvanic cells are set up between the bronze and the lead because the lead is not present in solid solution, but as a physical dispersion in the bronze. Furthermore, additional difficulties are encountered when welding is used for repairs made to pumps. The preheat necessary for gas welding sweats out the lead—leaving a porous casting. Several pumps with a composition of 80 percent copper, 10 percent tin and 10 percent lead had to be scrapped for this reason.

Attempts are being made to correct the troubles encountered with lead in copper-base alloys, especially when welding is used for repairs, by a reduction or an elimination of the lead in the analysis of the copper-base pumps. Pumps made of 90 percent copper and 10 percent tin are being tested at the present time. Because aluminum bronze has very satisfactory corrosion resistance, it was given consideration. However, difficulties encountered in obtaining non-porous

TABLE 9★

DESCRIPTION	SERVICE CONDITION		BODY		ROD		VALVES		SEATS		LINER		RINGS		HEADS		SPRINGS		PACKING		REMARKS
	Temper- ature °F.	Percent Corrosion	Material	Yrs. Life	Material	Yrs. Life	Material	Yrs. Life	Material	Yrs. Life	Material	Yrs. Life	Material	Yrs. Life	Material	Yrs. Life	Material	Yrs. Life	Material	Yrs. Life	
Concentrated Acid.....	80	100	Iron	5	Monel Illum	..	Monel Illum	..	..	..	..	..	..	..	..	..	..	..	..	..	None.
Concentrated Acid.....	Atm.	100	Iron	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	Thread corrosion at check valves.
Acid Contacted with H ₂ SO ₄ Sludge.....	50	88-98	Steel	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	Body life of 1/2 to 1 year.
Acid Sludge Transfer.....	90-120	88-80	Bronze	1/2	Bronze	1/2	Bronze	1/2	Bronze	1/2	Bronze	1/2	..	..	..	..	..	..	Rubber	..	Threads of valve seats cor- roded.
Acid Sludge Transfer.....	30-130	55-88	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	Centrifugal. Mechanite and cast iron throughout. 2 years life.
Acid Sludge Transfer.....	110	85	Bronze	3	Bronze	3	Bronze	1 1/2	Bronze	1 1/2	Iron	1	Bronze	1 1/2	Bronze	1 1/2	..	..	Rubber	1/2	General erosion.
Spent Alkylation Acid.....	90-90	85	Iron	6	18-8	1/2	..	..	..	..	..	..	..	..	..	..	..	..	Asbestos	1/2	General corrosion and wear.
Hydrocarbons.....	100	85	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	Rubber	3/4	Centrifugal. Cast iron threads. Body life 3 1/2 years. Erosion.
Hydrocarbons.....	200	75-85	Bronze	2-3	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	Centrifugal. Bronze through- out. Life of impeller 3-4 months. Erosion.
Lube Oil Sludge Pump.....	150	75-85	Bronze	5	Brass	1/2	Brass	1/2	Brass	1/2	Bronze	3/4	Bronze	1/2	Bronze	3/4	..	..	Asbestos	1/4	Body corrodes through. Rods score badly. Other parts fail by corrosion and erosion.
Lube Oil Sludge.....	180	84	Labour R 55	5-6	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	Centrifugal. Cast iron impeller. Life of impeller hour R 55 (32 Ni-23 Cr).
Spent Alkylation Acid.....	90-140	60-80	Bronze	4	..	..	..	..	..	..	..	..	..	..	..	..	..	..	Asbestos	..	Impeller life 1-2 years.
Lube Oil Sludge.....	80	78	Phos. Bronze	..	Phos. Bronze	..	Phos. Bronze	..	Phos. Bronze	..	Phos. Bronze	..	Phos. Bronze	..	Phos. Bronze	..	..	..	Rubber	..	General wear and corrosion.
Recovered Acid.....	80	78	Phos. Bronze	..	Phos. Bronze	..	Phos. Bronze	..	Phos. Bronze	..	Phos. Bronze	..	Phos. Bronze	..	Phos. Bronze	..	..	..	..	..	Minor repairs to valves springs and rods. Run 2 years to date.
Acid Sludge Transfer.....	80	78	Iron	3	Monel	3	Iron	3	Iron	3	Iron	3	..	..	..	..	..	..	Rubber	..	None.
Acid Sludge Transfer.....	150	75	Bronze	7	Bronze	2	Bronze	2	Bronze	2	Bronze	2	..	..	..	..	..	..	Rubber	1/2	General wear.
Sludge Transfer.....	30	75	Iron	1 1/2	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	Centrifugal. 6 mo. life. Cor- rosion.
Lube Oil Sludge.....	190	57	Brass	2	Bronze	1	Brass	1/2	Brass	1/2	Brass	1/2	Rubber	1/4	Brass	1	Bronze	1/2	Rubber	1/2	Body pinholed. Rods and liner scored.
Feed to Concentrators.....	125-150	55	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	Centrifugal. Hastelloy C impeller. Life of impeller 9 months. Durimet T shaft 2 years.
Kerosene Sludge.....	90-120	45-50	Bronze	9	Bronze	2 1/2	Monel	1/2	Bronze	1/2	Bronze	1	..	..	..	..	..	..	Asbestos	1/2	Failure by wear.
Acid Sludge Fuel.....	200	10-45	Bronze	2	Monel	2	Monel	1/2	Bronze	1/2	Monel	2	Monel	2	Monel	2	Monel	2	Rubber	1/2	Pump overhauled 3 times in 2 years.
Sludge and Weak Acid.....	180-200	35-40	Iron	5	Brass	2	Brass	1/2	Brass	1/2	Brass	1	Brass	1	Brass	1	Brass	1	Rubber	1/2	Body scrapped in 5 years.
Acid Sludge Fuel.....	43	43	Bronze	5	Monel	1	Monel	1	Monel	1	Monel	1	Brass	1	Brass	1	Monel	1	Rubber	1/2	Body badly holed. General corrosion.
Sludge and Weak Acid.....	220	35-40	Ampeco	10	Ampeco	10	Ampeco	18	Ampeco	20	Ampeco	20	Ampeco	18	Ampeco	10	Ampeco	10	Asbestos	1/2	Wear corrosion of valves and seats.
Sludge Transfer.....	200	10-30	Bronze	6	Resistal	1	K-Monel	1	K-Monel	1	Bronze	2 1/2	Bronze	1/2	Bronze	1	Bronze	1	..	..	Short life of parts because of wear and corrosion.
Recycling Acid.....	180	10-20	Brass	1 1/2	Brass	1 1/2	Brass	1/2	Brass	1/2	Brass	2 1/2	Brass	1/2	Brass	1/2	Brass	1/2	Rubber	1/2	Failures by corrosion.
Oil to Boiler House.....	180	4-5	Bronze	1 1/2	Bronze	1 1/2	Bronze	1/2	Bronze	1/2	Bronze	2 1/2	Bronze	1/2	Bronze	1/2	Bronze	1/2	Rubber	1/2	Centrifugal. All parts orthotic. Life of 2 to 2 1/2 years.
Wax Sludge.....	200	4-5	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	Rubber	1/2	Corrosion in a few spots.

★API Proceedings. Vol. 32M (111) (1982).

castings have led to rejection of this alloy for the present.

Many bronze pumps had screwed discharge and suction openings and these required the use of screwed piping. It was observed that the acid rapidly corroded the threads, thereby necessitating removal of the pump to the machine shop for repairs. In keeping with the policy of holding threaded connections to a minimum in sulfuric acid service, the pumps have been changed to flanged connections instead of threaded connections and this maintenance has been eliminated.

Many bronze pumps use brass piston rods. These rods, which became scored very easily and required replacement in about four months have been replaced with K-Monel rods. Teflon packing is also being used.

Where corrosion and erosion conditions are too severe for steel or copper-base alloys, cylinder sleeves of more corrosion resistant materials such as S-Monel are used.

Heating Coils for Sulfuric Acid and Sulfuric-Acid Sludges

Generally brass and lead are the materials used for heating coils in sulfuric acid or acid sludge, despite the relatively short service life.

In sludge service red-brass coils have failed by preferential corrosion of the parent metal adjacent to the welds. In one instance it was thought that, by covering the welds with lead, this preferential attack might be stopped. The position of the lead in the electromotive series suggested that, if galvanic cells were set up, the lead would be sacrificed with no damage to the brass coil. Furthermore, it was believed that the film formed on the lead would insulate it from attack and that no galvanic cell would be formed. However, in practice, the lead did not behave as predicted; instead a strong cell was set up in which the brass was rapidly corroded. This cell corrosion is shown in Figure 21.

Brass coils are corroded also by local cells caused by coke-like products which adhere to the brass surface. This type of corrosion results in deep pits.

It was thought that corrosion might have been accelerated by a cell action formed by the coil and the lead lining. One refinery reports that in future work all brass coils will be insulated from the tank

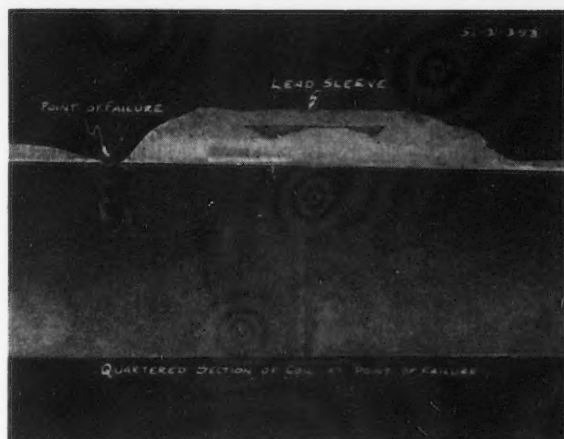


Figure 21—Galvanic cell corrosion caused by lead in direct contact with brass.



Figure 22—Failure of lead steam coil by rupturing.

so that no current flow can be established.

Lead Bond to Brass Must Be Good

Experiences with a lead-bonded brass coil were reported by one company. Local failures of the lead were discovered. In such areas where the brass was exposed, accelerated corrosion of the brass occurred. Further investigation showed that the failures resulted from poor bonding practices. The sections were

TABLE 10—Heating Coils*

DESCRIPTION	SERVICE CONDITION			HEATING COIL DATA				Remarks
	Contents	Temperature °F	Percent Concentration	Material	Fabrication	Steam Temperature °F	Life In Years	
Storage of Strong Acid.....	H ₂ SO ₄	50-70	98	Stainless Type 316	Welded	338	.....	1 year to date, no failure.
Sludge Separation.....	H ₂ SO ₄ Sludge	130	80	Red Brass	Brazed	.....	4	Leaks at brazed connections.
Heating Acid Sludges.....	H ₂ SO ₄ Sludge	140	75	Red Brass	Welded	400	1½	Heavy corrosion adjacent to welds.
Acid Recovery.....	H ₂ SO ₄	240	48-78	Lead	Burning	.....	2	Rupture after thinning.
Hydrolyzing Sludge.....	H ₂ SO ₄ Sludge	200-220	0-47	Lead	Burning	220	2	Corrosion-erosion.
Concentrators.....	H ₂ SO ₄	60-150	35-40	Lead	Burning	298	1½-2	Split by hammering condensate.
Cooking Kettles.....	H ₂ SO ₄	0-250	35-40	Lead	Burning	298	1	Split by hammering condensate.
Fluxing Kettles.....	H ₂ SO ₄	60-250	35-40	Lead	Burning	298	1½-2	Split by hammering condensate.
Treating Sludges.....	H ₂ SO ₄ Sludge	220	35-40	Red Brass	Brazed	275-320	7	None
Treating Sludges.....	H ₂ SO ₄ Sludge	180-200	30-40	Red Brass	Brazed	375	2	Corrosion-erosion.
Sludge Storage.....	H ₂ SO ₄ Sludge	175	28-30	Lead	Burning	250-300	½-2	Fails by twisting and turning.

* API Proceedings. Vol. 32M (III) (1952)

repaired and the coil was placed in service. The lead-bonded brass coil has operated to date, seven months without any further troubles. The areas where bonding is apparently good, have operated 17 months with no visual corrosion. It is believed that several years' service can be expected with good bonding practices.

Lead coils are extensively used in heating sulfuric acid or acid sludges. Lead coils have short service lives because of the low physical strength of lead. They usually fail by rupture as a result of pressure or steam hammering. A typical failure is shown in Figure 22.

Corrosion Data

Corrosion of materials is a complex mechanism depending upon many factors. Some factors which have a direct bearing upon sulfuric acid corrosion are:

- 1) acid temperature
- 2) velocity and turbulence
- 3) inhibitors and accelerators
- 4) electrolytic or galvanic action, and
- 5) concentration or strength of the acid

In studying corrosion by sulfuric acid, these factors should be considered. The effect of any one factor can be studied if all other factors or conditions are ideal, or at least controllable. The individual effect of each of these factors will be discussed in the following paragraphs. With actual corrosion problems, however, often it is necessary to evaluate corrosivity as influenced by a combination of several factors.

Temperature Factors

In general, sulfuric acid becomes increasingly corrosive as the temperature of the acid increases. This is not invariably true because of the oxygen dissolved in the acid. Sulfuric acid which contains oxygen corrodes some materials (particularly copper-base alloys) to a greater extent than acid which is oxygen-free; and in such cases, inasmuch as increasing temperatures reduce the solubility of the oxygen in the acid, reduced corrosion rates may result. However, temperature increases beyond the point required to expel oxygen in all probability will increase corrosion.

Velocity and Turbulence

Most metallic materials in contact with sulfuric acid produce corrosion products which unite to form continuous films which protect the material from further attack. Such protective films can often be destroyed by fluid velocity or turbulence. When destruction of the protective film occurs, corrosion proceeds at a uniform rate. For example, static tests of steel in sulfuric acid which has a pH of 3.5 gave a corrosion rate of 0.04-inch per year. This same steel, acted upon by identical acid under conditions of high velocity, showed an erosion-corrosion rate of 0.5-inch per year, or about a twelvefold increase. In another instance it was reported that acid in the concentration range of 70-75 percent which would normally be only mildly corrosive to carbon steel, caused corrosive attack of the magnitude of five inches to 25 inches of penetration per year at flow velocities greater than 10 feet per sec. when flow was vertical to the metal surface. Under the same velocity condi-

tions but with flow parallel to the surface the corrosion rate in this case was only 50 to 100 mils per year.

Accelerators and Inhibitors

Sulfuric acid is not only encountered as concentrated acid and acid-water solutions, but also as a component of sludges or other mixtures. Sludges formed by the chemical action of sulfuric acid on petroleum stocks often contain foreign substances which act to accelerate or to inhibit the corrosive action of the acid. These accelerators or inhibitors, as the case may be, are formed by secondary or side-line reactions during the treating processes.

Galvanic Effects

When dissimilar metals are contacted and exposed to sulfuric acid, electrolytic or galvanic action may proceed. A current flow is established which, generally, is dependent upon the relative positions of the metals in the electromotive series. In such cases the more noble metal (higher in the electromotive series) will cause displacement of the other metal. Several examples of galvanic corrosion have been referred to in other sections of this paper. It follows that care should be taken in the design of sulfuric-acid equipment so that conditions conducive to galvanic corrosion are eliminated or at least minimized.

Concentration Factors

Probably the most important of the factors which affect corrosion is the strength or concentration of sulfuric acid. It is the most difficult factor to take into account, because no general rule can be established regarding the corrosion as affected by concentration. For example, corrosion may be said to increase with increasing velocity or temperature, but no generalization can be made which would show the corrosion to be the result of concentration increases or decreases.

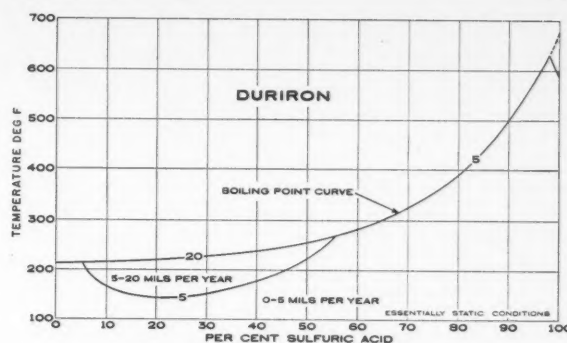
The corrosion of an acid sludge is similar to the corrosion which would be expected from an acid of the same concentration as the acid present in the sludge. Consequently, it is important, in evaluating suitable materials for use in acid sludges, to know whether the sludge contains a weak or strong acid. Therefore, in corrosion work, the concentration of the sulfuric acid in the sludge should be expressed as percent by weight of sulfuric acid, considering only the sulfuric acid and water present. In noting the concentration of the acid in a sludge, care must be exercised because it is common to express the acid concentration as a percent of the entire solution or mixture. For instance, a sludge which contains 50 percent hydrocarbons and 50 percent concentrated acid might be reported as containing 50 percent sulfuric acid. Actually the acid concentration might be 90 or 95 percent, depending upon the initial strength of the treating acid and the amount of water dilution. Compositions and corrosion rates of various materials in acid sludges are given in Tables 11 and 12.

Design and Use Must Be Considered

When considering a particular material for han-

handling sulfuric acid or acid sludge, a knowledge of the physical properties, functional design, and corrosion behavior is required. The importance of functional design is illustrated by the following example: A steel tank may be suitable for handling strong sulfuric acid, mainly because in this type of equipment corrosion allowances in the form of thicker plates can be made. However, carbon steel might not be suitable for the construction of an instrument for which close tolerances must be maintained and for which corrosion allowances usually cannot be provided. Although the corrosion rate is identical with both pieces of equipment, steel is a satisfactory material for the tank, but unsatisfactory for the instrument.

Steel is largely used in the construction of tanks and lines because it has the desirable physical properties, because it has suitably low corrosion rates in strong acid, and because it is one of the least expensive materials of construction. With some types of equipment which operate at room temperature, steel is an economical material of construction for sulfuric acid concentrations as low as 65 percent. However, as mentioned previously, steel is used more extensively for concentrations in excess of 75 percent by weight of sulfuric acid—largely because operating temperatures are usually higher than room temperatures and also because of the possibility of unavoidable or accidental dilution of the acid with water. Figure 16 shows the corrosion of 0.20 percent carbon steel as a function of both concentration and temperature of acid. Exposure was made under static conditions. The corrosion of steel in strong sulfuric acid is complicated, as shown by the peculiar dips

Figure 23—Corrosion of Duriron by sulfuric acid.⁹

in the curves (high corrosion rates), around 100 or 101 percent. Thus the selection of steel for service in acid at these temperatures and concentrations requires close scrutiny. It can be seen that steel in contact with an acid whose concentration is less than 65 percent is unsatisfactory at any temperature. Cast iron exhibits similar corrosion behavior in sulfuric acid service. However, its use in sulfuric acid which contains free SO_3 (more than 100 percent concentration of acid) should be avoided. It has been reported that free SO_3 results in cracking of cast iron.

Duriron Resistance Is Excellent

Duriron has excellent erosion-corrosion resistance to sulfuric acid at all concentrations up to 100 percent and at all temperatures up to and including boil-

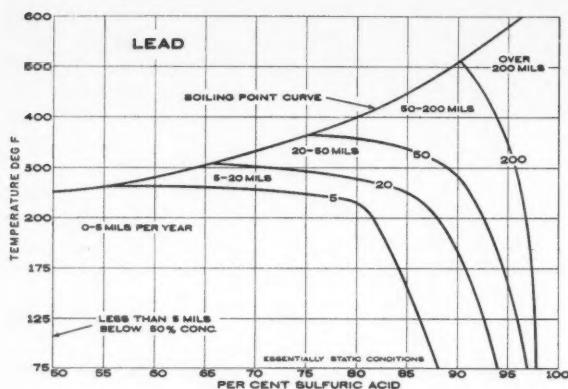
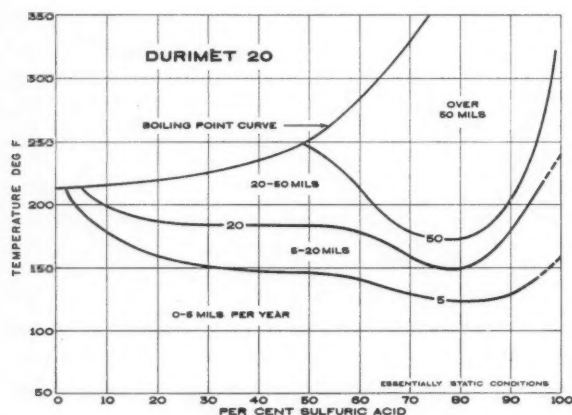
TABLE 11

SERVICE CONDITIONS		CORROSION RATES OF ALLOYS IN SULFURIC ACID AND ACID SLUDGES—INCHES PENETRATION PER YEAR																
CORROSIVE MEDIA AND TEMPERATURE	% Concentration	Aloyco 20	Aloyco 33	Aloyco 35	Aloyco 37	Ampco 8	Ampco 18	Chemical Lead	Cupro Nickel	Durimet T	Duriron	Hastelloy B	Hastelloy C	Hastelloy D	Monel	Red Brass	Stainless Type 309	Worthite
H ₂ SO ₄ , Hydrocarbons 90–110° F.....	65	.0101	.....	.0062	.0036	.....	.0107	.....	.0027	.0155	.....	.0003	.0020	.0003	.0034	.0044	.0281	.0136
H ₂ SO ₄ , Hydrocarbons Free Carbon 160° F.....	65	.0005	.0011	.0005	.....	.....	.0038	.0024	.....	.....	.....	.0009	.....	.0034	.0030	.....	.....	.....
H ₂ SO ₄ , Sludge (Occasional 10-98 Percent) 150-230° F....	30-60	.0486	.....	.0296	.0449	.0216	.....	.....	.....	.....	.0048	.0083	.0345	.0351	.0304	.....	.....	.0374
H ₂ SO ₄ , Sludge 113-176° F.....	56	.0152	.....	.0000	.0296	.....	.0012	.0004	.....	.....	.....	.0014	.....	.0010	.....	.....	.....	.0094
H ₂ SO ₄ , 200° F.....	10-45	.0686	.0247	.0697	.0279	.....	.....	.....	.....	.....	.....	.0044	.0682	.....	.....	.....	.....	.0490
H ₂ SO ₄ , Sludge 190-225° F.....	35	.0298	.0045	.0002	.....	.....	.0074	.....	.0632	.....	.....	.....	.....	.....	.0233	.....	.....	.....
Acid and G. A. Soaps 170° F.....	28-30	.0258	.0098	.0539	.0024	.0074	.0196	.....	.....	.....	.....	.0173	.0300	.0140	.....	.....	.....	.....

TABLE 12*

CORROSION RATES EXPRESSED IN INCHES PENETRATION PER MONTH																
Percent Acid	RATES AT 100°F				RATES AT 150°F				RATES AT 175°F				RATES AT 200°F			
	Type 304	Type 310	Type 316	Type 317	Type 304	Type 310	Type 316	Type 317	Type 304	Type 310	Type 316	Type 317	Type 304	Type 310	Type 316	Type 317
1/2	.0032	Nil	Nil	Nil	.0183	Nil	Nil	Nil	.0309	.0038	Nil	Nil	.0638	.0041	.0002	Nil
1	.0048	.0003	Nil	Nil	.0177	.0035	Nil	Nil	.0287	.0069	Nil	Nil	.0627	.0065	.0046	Nil
2	.....	.0005	Nil	Nil	.....	.0048	Nil	Nil	.....	.0084	.0004	Nil	.....	.0092	.0067	.0049
3	.0055	.0005	Nil	Nil	.0326	.0057	.0007	Nil	.0442	.0094	.0034	.0005	.1112	.0108	.0075	.0098
4	.....	.0017	Nil	Nil	.....	.0056	.0012	Nil	.....	.0108	.0048	.0005	.....	.0130	.0083	.0121
5	.0137	.0022	Nil	Nil	.0939	.0072	.0032	.0004	.1286	.0137	.0069	.0075	.4504	.0143	.0120	.1099
6	.....	.....	Nil	Nil	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
7	.....	.....	Nil	Nil	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
8	.....	.....	Nil	Nil	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
9	.....	.....	Nil	Nil	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
10	.0294	.0162	.0007	Nil	.1475	.1274	.0062	.0065	.3779	.2210	.0127	.0159	.4911	.2314	.0189	.0466
11	.....	.....	.0025	.0009	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
12	.....	.....	.0032	.0015	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
13	.....	.....	.0044	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
20	.0779	.0330	.0062	.0020	.4763	.2170	.0156	.0168	.9042	.4440	.0615	.0489	1.75	1.11	.1475	.0886
40	.0746	.0661	.0690	.0169	1.10	.3822	.5390	.2255	2.82	.7293	1.510	.8068	6.69	1.96	3.053	2.375
60	.1213	.1028	.2367	.2305	1.46	.7079	1.300	.9284	3.49	1.22	2.849	2.318	8.67	2.48	5.106	4.605
80	.0612	.0276	.0225	.0485	.1054	.1520	.0485	.0909	.1878	.5307	.0968	.2938	.6897	.8140	.3311	.5055
95	.0003	.0003	Nil	Nil	.0117	.0209	.0052	.0072	.0115	.0212	.0065	.0210	.0149	.0296	.0307	.0460

* George C. Kiefer, and W.G. Renshaw, The Behavior of the Chromium Nickel Stainless Steels in Sulfuric Acid. Corrosion, Vol. 6, No. 8, 235–244, (1950) August.

Figure 24—Corrosion of lead by sulfuric acid.⁹Figure 25—Corrosion of Durimet by sulfuric acid.⁹

ing. It is a cast iron which contains about 14 percent silicon. Duriron is susceptible to damage from physical and thermal shock and must be handled with a reasonable degree of care. It possesses an inherently high hardness, which makes it difficult to machine;

therefore, this operation is usually done by grinding. The hardness of Duriron is an asset in that hardness imparts erosion resistance to the alloy. Figure 23 shows the corrosion rates for Duriron as a function of both temperature and concentration of acid. It has excellent resistance to sulfuric acid at all concentrations except those from 10 to 50 percent, where its resistance is considered quite satisfactory. However, this alloy is not recommended for service in oleum or acid whose strength is above 100 percent because of its cracking tendency in these acids.

Lead Is Used Extensively

Lead is extensively used in the handling of sulfuric acid, a service in which it depends on the formation of a protective film for its corrosion resistance. At room temperature lead has satisfactory corrosion resistance to all concentrations of sulfuric acid up to approximately 95 percent. However, higher acid concentrations apparently destroy the protective film—with the result that lead dissolves rapidly, particularly in the presence of sulfuric acid strengths of 98 percent and greater.

Lead has excellent corrosion resistance to sulfuric acid concentrations of less than about 50 percent at all temperatures including boiling; and, at elevated temperatures, it has satisfactory corrosion resistance to sulfuric acid concentrations up to about 80 percent. If the concentration is more than 80 percent, the corrosion rate of lead at elevated temperatures increases rapidly. Figure 24 gives the static corrosion rates for lead in sulfuric acid. Concentrations of less than 50 percent are not shown because, as mentioned previously, the corrosion resistance of lead in such service is excellent at all temperatures.

Velocities sufficient to remove the protective film would result in increased corrosion rates and would change considerably the shape of the curves shown in Figure 24.

A harder lead is used when slightly higher fiber stresses are required. The hard lead is obtained by adding from 4 to 12 percent antimony. Antimonial lead has about the same corrosion resistance as chemical lead, but has a higher strength up to 250 degrees F. At temperatures above 250 degrees F, chemical lead is stronger. Inasmuch as lead is physically weak, it is generally used in conjunction with a common structural material such as steel. Tanks which handle weak sulfuric acid or acid sludge are lead lined. Lead is vulnerable to erosion because of its softness. In equipment in which abrasion or high velocities are encountered, the protective film of lead sulfate is often destroyed and corrosion proceeds at a substantial rate.

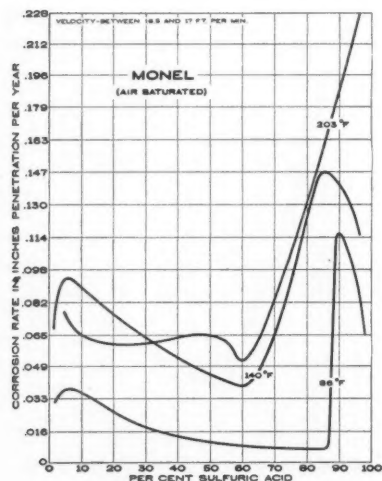


Figure 26—Corrosion of Monel by air-saturated sulfuric acid.

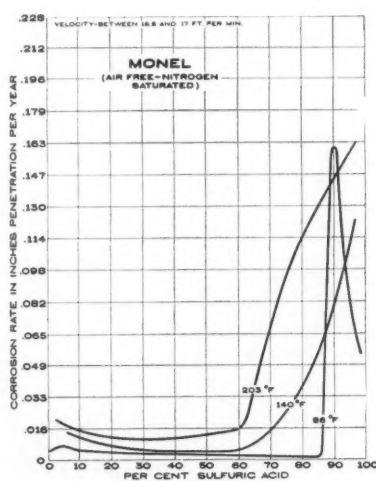
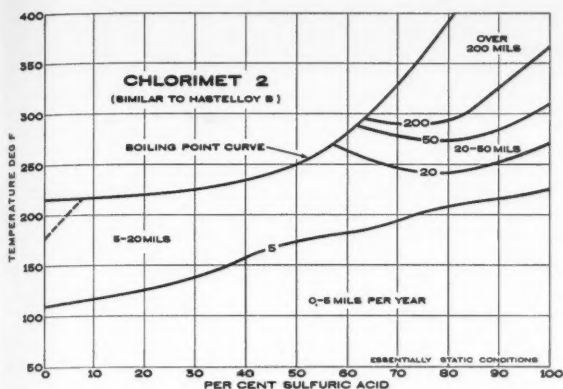


Figure 27—Corrosion of Monel by air-free (nitrogen saturated) sulfuric acid.

Stainless Steels Used in Some Instances

Stainless steels are characterized

Figure 28—Corrosion of Chlorimet² by sulfuric acid.⁹

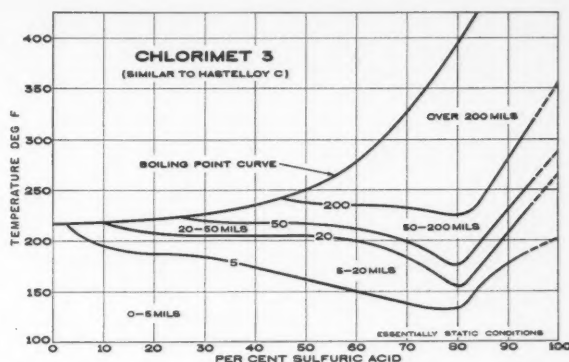
by their ability to form a protective surface in some concentrations of sulfuric acid. This protective surface is the only barrier to attack and, once it has been destroyed, these steels exhibit the same tendency to corrode as ordinary mild steel. The passive state of stainless steels is usually favored by an oxidizing type of environment, whereas reducing conditions tend to promote activation.

The regular chromium-nickel stainless steels (Types 304 and 310) remain active in practically all concentrations of sulfuric acid, even at 100 degrees F. The 18-8 type of stainless steels which contain molybdenum (Types 316 and 317) show more satisfactory resistance than those without molybdenum (Types 304 and 310). Types 316 and 317 are passive, or they have zero corrosion rates in sulfuric acid concentrations up to 9 and 11 percent, respectively, at 100 degrees F; 3 and 5 percent at 150 degrees F; 2 and 4 percent at 175 degrees F and 0.5 and 1 percent at 200 degrees F.

As indicated by these figures, molybdenum-bearing stainless steels have low corrosion rates in very dilute solutions of sulfuric acid. With the stainless steels maximum corrosion occurs in about 60 to 70 percent sulfuric acid; whereas the maximum corrosion of mild steel occurs in much weaker concentrations. Inasmuch as Types 316 and 317 stainless steels are resistant to sulfuric acid in only the very weakest and strongest concentrations, and Types 304 and 310 in strong sulfuric acid, their use for acid applications in the refinery is quite limited. Table 12 presents corrosion rates of four stainless steels in sulfuric acid.

High-Nickel Chromium Steels Successful

High nickel-chromium steels used in sulfuric acid or acid sludges are marketed under trade names such as Durimet 20, Esco 20, FA-20, and Alloy 20, 35 and 37. Such alloys are composed of chromium and nickel in percentages in excess of 20 and small percentages of such elements as copper, molybdenum and silicon. These alloys are widely used for valves in sulfuric acid service, particularly for strong acid at moderate temperature. Alloys of the 20 type have been successfully used in service where either strong or weak sulfuric acid is handled. The merits of such

Figure 29—Corrosion of Chlorimet³ by sulfuric acid.⁹

installations have been discussed in the section of this paper devoted to valves.

In extending the uses of the high nickel-chromium alloys, considerable testing has been done. Inasmuch as the conditions of plant operations in handling and processing acid sludges are not entirely reproducible on a laboratory scale, the exposure tests were performed in actual service. The alloy composition, solution conditions, and corrosion rates are presented in Tables 8 and 11. Figure 25 indicates the corrosion of Durimet 20 for static exposure in pure sulfuric acid. Type 20 alloys have satisfactory corrosion resistance to all concentrations of acid when temperatures are maintained below 150 degrees F. The corrosion resistance of these alloys to oleum or fuming sulfuric acid is quite satisfactory.

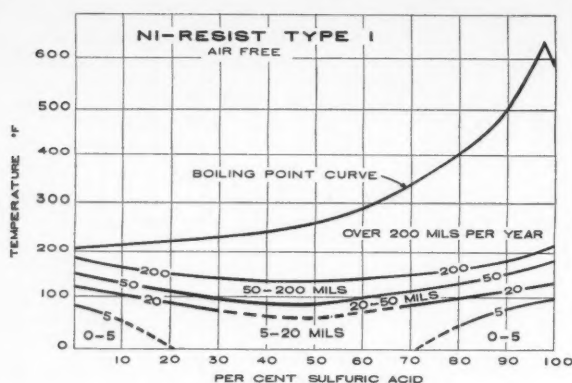
Monel Is Widely Used

Alloys known as Monel contain about two-thirds nickel and one-third copper. Monel is widely used for pump and valve parts because it has desirable physical properties in addition to its corrosion resistance. Monel can be obtained in varieties (by slight change in composition) which are hard and abrasion resistant. This abrasion resistance promotes the use of such types of Monel in pump and valve parts. Corrosion of Monel alloys in sulfuric acid concentrations below 85 percent, or in acid sludges whose acid concentration is less than 85 percent, is low at room temperatures. However, in stronger acid, corrosion resistance rapidly decreases. Typical curves which show corrosion rates for Monel are Figures 26 and 27.

Hastelloys and Chlorimets

Nickel-base alloys known as the Hastelloys and Chlorimets are used for sulfuric acids and sludges under conditions which are too severe for other materials of construction. This class of alloys is one of the few which generally have satisfactory corrosion resistance to sulfuric acid and sludges at temperatures above 200 degrees F. Typical corrosion rate curves for Chlorimet 2 and 3 are shown in Figures 28 and 29. The corrosion resistance of Chlorimet 2 and 3 is similar to the corrosion resistance of Hastelloy B and C, respectively.

High-nickel cast iron containing copper and chro-

Figure 30—Corrosion of Ni-Resist by sulfuric acid.⁹

mium is known as Ni-Resist, Ni-Resist is sometimes used for handling sulfuric acid at low concentrations and low temperatures. A typical corrosion rate curve showing the effect of concentrations and temperature is presented in Figure 30.

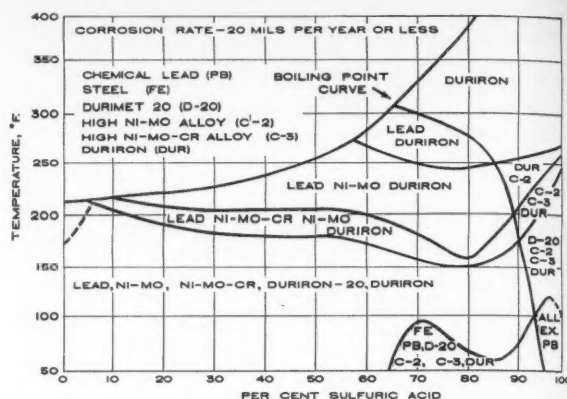
Figure 31 presents a combined picture of the corrosion resistance of six metals. The chart is plotted for 20 mils per year or less. Those materials listed within any boundary have a corrosion rate of 20 mils per year or less for the conditions of temperature and concentration within the boundary lines.

Survey Data in Tables

Table 1 revealed that carbon steel was used for tanks in sulfuric acid and acid sludge where the concentration of the acid was maintained in excess of 77 percent. The tanks were of both riveted and welded construction. One welded tank was reported to have leaked as a result of corrosion attack at the welds. This tank was in 104 percent acid service and was repaired by placing Hastelloy B overlays over the welded seams. Riveted and welded steel tanks in acid or sludge service, when the acid concentration was in excess of 77 percent were reported to be satisfactory. With respect to sulfuric acid or acid sludges of concentrations of less than 77 percent, the survey shows that steel is unsatisfactory. For this service the tanks are constructed of steel, lined with lead. In some instances the lead is protected by brick. Lead linings fail because of fatigue, creep or steam erosion.

The survey of valves shows that, in sulfuric acid of strengths greater than 75 percent, steel and iron valves were used with little success. The short life of steel and iron valves is attributable to seat, gate and stem failures. Alloy 20 valves which in some instances replaced these iron and steel valves gave service lives as long as six years. It appears that Alloy 20 valves are satisfactory for strong sulfuric acid, provided the temperature is not too high. In services which involve sulfuric acid and acid sludges of concentrations of less than 75 percent, the data on valves are limited. Metals which have been used are monel, brass, bronze, Alloy 20 and lead. Data on valves are given in Table 4.

The information on lines presented in Table 2 shows that steel piping is used in services where the

Figure 31—Combined chart of corrosion of six metals and alloys by sulfuric acid.⁹

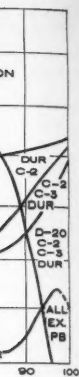
acid concentrations are in excess of 75 percent. In many cases the life of the steel pipe was reported to be five to 10 years. When screwed construction is practiced, corrosion of the threads is responsible for early failures. When the pipe was welded, failures usually occurred in the weld metal or in the metal adjacent to the weld. In acid concentrations of less than 75 percent, piping generally was constructed of brass or lead. As with steel piping, brass pipe corrodes at the threads and welds. Lead lines fail by erosion and rupture.

Tank heating coils (Table 10) are generally constructed of lead and red brass for all concentrations of sulfuric acid or acid sludges. Lead fails because of its low physical strength. Red-brass coils have service lives ranging from two to seven years. In one instance Type 316 stainless steel was used in 98 percent acid.

The materials used in centrifugal and reciprocating pumps, in general, are the same. Bronze and brass parts are used for pumps which handle acids and sludges with concentrations of less than 85 percent. As shown in Table 9, the service lives of the materials vary over a wide range. Body life is from 1/3 to 9 years; rods, from 1/6 to 3 years; seats and valves, from 1/4 to 3 years. Such short service lives are a result of wear as well as corrosion. Liners were largely of the same composition as the bodies. Service lives of the liners varied from 1/4 to 1 1/2 years. Monel, bronze and brass piston rings were reported to have given from 1/4 to 1 year's service. The data with respect to concentrated acid are quite limited; but, for concentrations in excess of 88 percent, iron and steel have been used. Packing for rods and plungers failed in periods ranging from one week to six months.

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 9. Figures 16, 24, 25, 28 and 29 copyrighted 1951; Figures 23, 31 copyrighted 1952; Figure 30 copyrighted 1953 by the American Chemical Society and reprinted by permission of the copyright owner.

DISCUSSION*

Discussion by Kempton H. Roll, Lead Industries Association, New York:

For the rather severe conditions under which you have described several applications of lead coils, lead covered copper or brass heating coils have been developed and successfully applied under conditions where a lead coil alone would not be recommended. For example, the upper limit of steam pressure for a lead coil is 50 lb. whereas the lead covered copper will sustain pressures up to 150 lb. without undue strain while retaining the corrosion resistance of lead and heat transfer characteristics of copper. What has your experience been with this new type of lead covered heating coil?

Reply by V. J. Groth and R. J. Hafsten:

We know of one case mentioned in the paper where a lead bonded brass coil operated about two years to date without any difficulty where lead bonding was of good quality. Previous to the use of the lead bonded coil a brass coil required repair because of corrosion after about six months. As pointed out in the article the difficulty with lead covered brass coils is the trouble encountered with galvanic corrosion if the lead is damaged.

Question by Robert B. Scrimgeour, The Pfaudler Co., Rochester, N.Y.:

Glass lined pipe should be satisfactory for all sulfuric concentrations including oleum up to 300-350 degrees F. Since steaming the pipe could cause cracking of the glass lining, what temperature of steam was used to clean?

Reply by V. J. Groth and R. J. Hafsten:

The 340 degree steam used probably caused failure. A maximum of 200 degrees differential is recommended to prevent glass lining failure due to thermal shock.

Question by Werner O. Tunderman, Rahway, N.J.:

Have you had any experience with desiccators in vent lines for your fuming sulfuric acid and (80-100 percent) strong sulfuric acid storage tanks?

Reply by V. J. Groth and R. J. Hafsten:

We have no experience with desiccators.

*These discussions were not a part of the original publication but were derived from the NACE presentation.

Question by R. S. Treseder, Shell Development Co., Emeryville, Cal.:

Mention was made that it is possible in laboratory tests to reproduce the selective attack adjacent to welds in steels exposed to concentrated sulfuric acid. Could you describe the conditions employed in these laboratory tests?

Reply by V. J. Groth and R. J. Hafsten:

A 50 percent sulfuric acid solution was used in the tests to demonstrate the selective attack of welds and in some cases adjacent parent metal. We were not able to obtain this selective attack when the test specimens were exposed to concentrated sulfuric acid, the main reason being that in laboratory tests with concentrated acid at ordinary temperatures corrosion of steel is negligible.

Question by Edgar Carl Winegartner, Humble Oil and Refining Co., Baytown, Texas:

Do the authors have any experience with aluminum bronze in acid sludge lines?

Reply by V. J. Groth and R. J. Hafsten:

The paper includes corrosion rate data on aluminum bronze. It is referred to as Ampco 8 and Ampco 18. In general aluminum bronze alloys are more corrosion resistant than other bronze and brass alloys and it is a matter of economics whether they should be used in their place.

Question by George W. Hill, Baton Rouge, La.:

Do the authors use Alloy 20 valves or alloy trimmed valves?

Reply by V. J. Groth and R. J. Hafsten:

Alloy 20 valves referred to in the article are solid Alloy 20 valves.

Questions by Kenneth Eldridge Honeycutt, Freeport, Texas:

1. Did discussion cover sulfuric acid with organic impurities only?
2. Could cast iron pipe have been used?

Replies by V. J. Groth and R. J. Hafsten:

1. Not necessarily. Undoubtedly there were inorganic impurities, including copper and other metals which would be present as a result of reaction among steel, brass and lead equipment and sulfuric acid.

2. From the corrosion viewpoint cast iron could be used in concentrated sulfuric acid service except for the higher concentrations where the cracking of the iron may result. In many instances it is the safety aspect which governs in deciding if the installation can tolerate the less desirable physical characteristics of cast iron as a substitute for steel.

Discussion by Robert R. Pierce, Pennsylvania Salt Manufacturing Co., Pennsylvania:

Two case histories are submitted which have a direct relation to Mr. Hafsten's paper. One covers the use

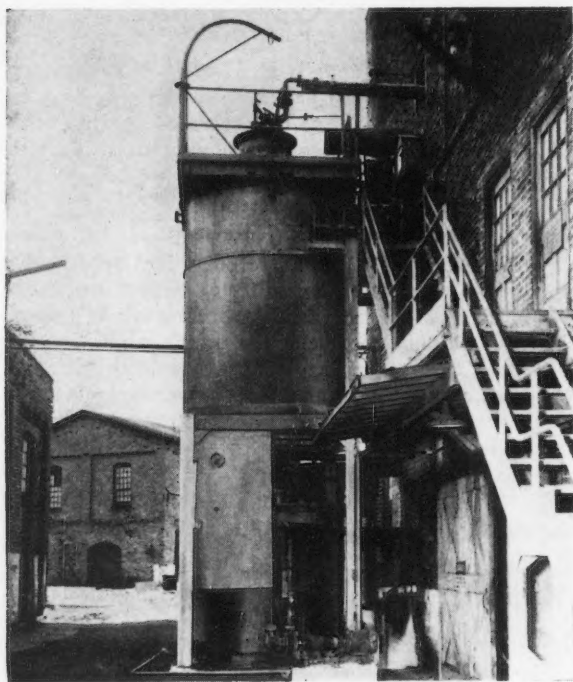


Figure 1—A tank at a Pennsylvania Salt Manufacturing Co. plant handling sulfuric acid, chlorinated organics and some hydrochloric acid at temperatures over 400 degrees F. Lead in the tanks is protected by brickwork. Although some corrosives get through the brick to the lead insoluble salts formed on the lead protect it.

of lead and brickwork in sulfuric acid at high temperatures and the other at low temperatures.

We have several vessels in our company which must handle a process operation consisting of about 50 percent sulfuric acid plus organic at over 400 degrees F. For this construction we use both sheet and homogeneous lead lined steel vessels properly designed for brickwork, and we use nine inches of brick bonded with acid resistant cement. The brickwork is designed to keep the lead under compression so that the lead does not grow or that the brickwork does not heave on the bottom. We have operated these vessels for many years under these extreme conditions where we have proved in the past that lead alone would last only a matter of weeks.

The other case history involves 35 percent sulfuric acid plus heavy organics at 125 degrees F. Here the vessel was constructed originally with 16-pound lead

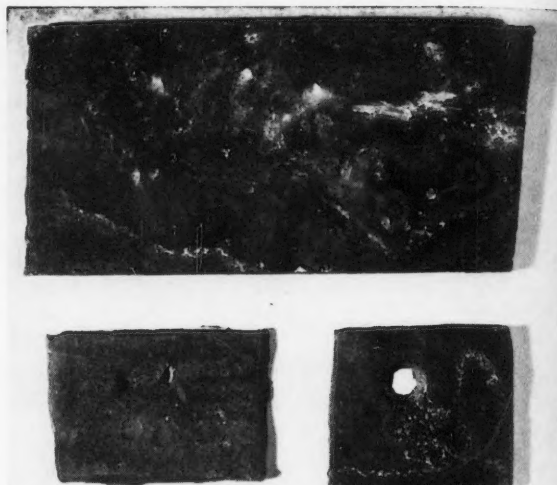


Figure 2—Top: Specimen of 20-lb. lead taken from the floor of a process vessel handling 35 percent sulfuric acid plus cool tars at 120 degrees F after 13 years service. The lead was protected by a course of hard-burned high-silica acid resisting brick. Although 16-lb. lead walls (bottom) unprotected by brick, were replaced three times in this period the lead floor was virtually undamaged.

on the walls and 20-pound lead on the bottom. The bottom was protected by $4\frac{1}{2}$ inches of brickwork bonded with acid resistant cement. About once every four years it is necessary to replace the lead on the walls due to a scab-type of pitting or drilling action. After 13 years the vessel was reconstructed and the lead on the bottom had never been disturbed or repaired. On removal of the brickwork it was found that the lead under the brickwork was in perfect condition. In this instance the brickwork had been designed to keep the lead from growing, while the scabbing or drilling action had been stopped completely by the layer of brickwork which had been added.

When the tank was rebuilt it was completely lined with brick.

This experience indicates that in many instances when lead alone is inadequate, a combination of lead and brickwork gives good service. It is the writer's further belief that in many cases when lead has been discarded as being unsuitable for handling corrosives under conditions involving high temperatures and temperature changes it would have proved fully satisfactory had it been protected by brickwork.

Corrosion Resistance of Cupronickel Alloys Containing 10 to 30 Percent Nickel*

By FRANK L. LaQUE

Introduction

THE CUPRONICKEL alloys that contain 10 percent to 30 percent nickel have come into rather extensive use, principally in the form of tubes for heat exchangers where they have been chosen primarily to resist attack by salt waters used for cooling. More recently, there has been considerable application for tubes in boiler feedwater heaters. In this service the desired feature of the alloys has been their superiority over other copper alloys in maintaining strength at the elevated temperatures encountered in modern high pressure steam power plants. The Standards of Bleeder Heater Manufacturers Association, Inc., limit the use of arsenical copper to 400 degrees F, Admiralty Brass to 450 degrees F, 90/10 cupronickel to 600 degrees F and 80/20 and 70/30 cupronickels to 700 degrees F.

In these common applications the principal requirements of corrosion resistance have involved resistance to impingement attack, erosion and pitting by salt waters, steam and boiler waters. A considerable mass of data have been accumulated and published with respect to behavior in salt waters, as, for example, in papers by Tracy and Hungerford,¹ LaQue and Mason,² Bailey,³ Stewart and LaQue⁴ and a recent one by Gilbert.⁵

The applications in marine and power service have gradually been extended to other industries, especially in petroleum and chemical process equipment. Here again, the principal uses have been in the form of tubes for heat exchangers, although the alloys are available in most other wrought forms. Thus, there is considerable interest in how these alloys may resist attack by corrosive media other than the waters used for cooling purposes. It is the purpose of this paper to provide some information of this sort as a guide in the selection of the alloys where product side corrosion must be given as much consideration as resistance to attack by waters.

Data on the corrosion resisting characteristics of the cupronickel alloys have been secured in two principal ways.

- 1) systematic studies of a series of alloys of varying nickel content in particular media chosen to disclose basic effects of composition and
- 2) spot plant tests of commercial alloys exposed in operating equipment. Information from both types of investigation will be drawn upon in this paper but principal attention will be given tests in operating equipment in several industries.

*A paper presented at the Tenth Annual Conference, National Association of Corrosion Engineers, Kansas City, Mo., March 15-19, 1954.



FRANK L. LaQUE—Manager of the Development and Research Division, The International Nickel Co., Inc., New York, Mr. LaQue has been prominent in the promotion of corrosion studies and the dissemination of corrosion-control data for many years. A past-president of NACE, he is a member of and has held responsible positions in many other technical organizations concerned with corrosion. He has been the recipient of many honors for his work in corrosion and has published numerous technical papers both in the United States and abroad.

Abstract

Because there has been a gradual extension to industries other than the power generation industry of the use of cupronickel alloys containing 10 to 30 percent nickel the author considers it pertinent to provide information on their resistance to corrosives other than cooling waters. This is needed because the alloys' use in heat exchanger tubes in applications where one side is exposed to various corrosives at high temperatures makes their reaction to the product side corrosive as significant as the attack on the water side.

After outlining the basic homogeneous character of the copper-nickel alloys, the author discusses the theoretical aspects of their corrosion characteristics. Tables and figures outline results of certain tests of the alloys under various stresses and exposed to various environments.

Data collected on performance in specific service are then appended, principally in the form of tabulated information, on waters other than salt waters, ammoniacal solutions, brines, alkaline solutions, petroleum products containing hydrogen sulfide, miscellaneous petroleum products, organic compounds, chlorinated solvents, sulfuric acid, halogens and halogen compounds, paper stock suspensions. 19 references, 5 figures, 15 tables.

Basic Considerations

Copper and nickel are soluble in each other in all proportions. The phase diagram, a classical example of its type, shows a continuous series of solid solutions with no eutectics, intermetallic compounds or phases of different composition. Thus, all of the alloys can be expected to be homogeneous and free from selective attack or the peculiar forms of corrosion that are sometimes encountered in heterogeneous alloys. It can be expected, also, that effects of composition on corrosion in many environments will show gradual trends that will reflect some powerful effect of either nickel or copper. This will permit reasonably reliable interpolation from data on compositions that bracket the one of particular interest. This will be illustrated, for example, by behavior in caustic soda to be discussed later.

In the electromotive series, copper lies on the

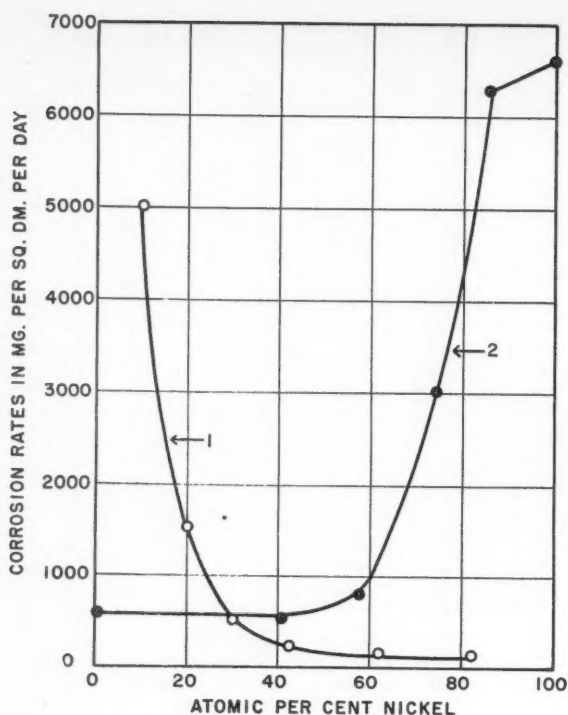


Figure 1—Effects of nickel content on corrosion of copper-nickel alloys. o—1. Tests in 20 percent HNO_3 . o—2. Tests in 63 percent H_2SO_4 .

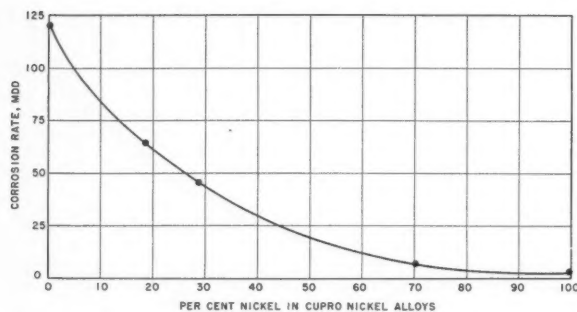


Figure 2—Results of corrosion tests of cupronickel alloys in 50 percent caustic soda evaporator.

more noble side of hydrogen with a standard potential of +0.345 volt, while nickel lies on the less noble side with a standard potential of -0.250 volt. Thus, the high copper alloys should inherently be more corrosion resistant than the high nickel alloys. However, nickel has the property of acquiring passivity in media of adequate oxidizing power so that, in some environments, the high nickel alloys resist corrosion better than the high copper ones. These opposing trends are illustrated by Figure 1 based on tests in aerated 63 percent sulfuric acid at 95 degrees C (203 degrees F) reported by Irrmann and tests in 20 percent nitric acid undertaken by Waehlert and summarized in a paper by Landau and Oldach.⁶

Some additional trend effects were illustrated by data from tests in several media reported by Claus and Herrman.⁷

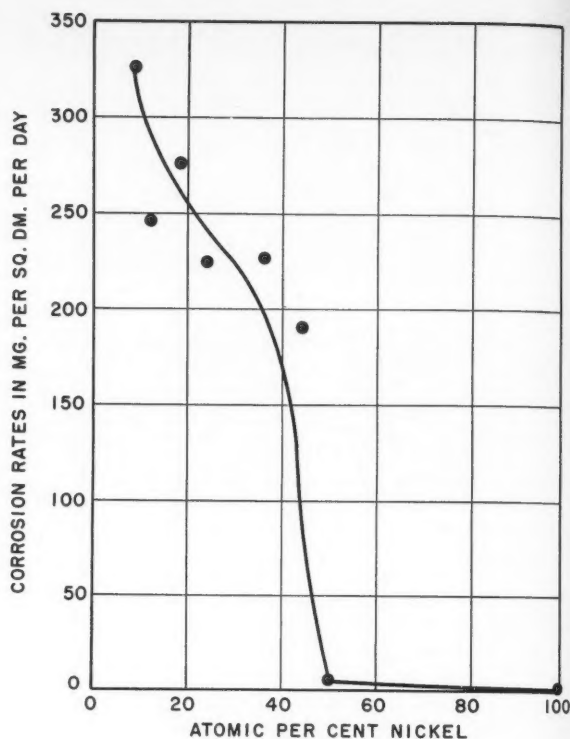


Figure 3—Effect of nickel content on corrosion of copper nickel alloys by unaerated 12 percent NH_4OH .

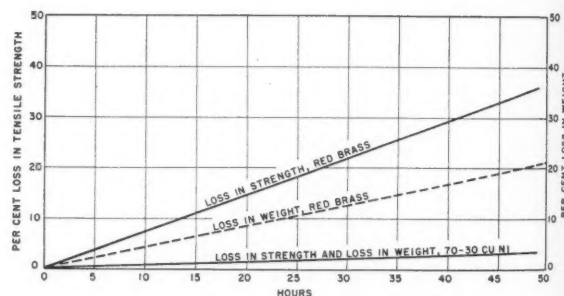


Figure 4—Stress corrosion tests in ammoniacal atmosphere (Bulow).

TABLE 1—Results of Tests on Alloys Under Stress In Moist Ammoniacal Atmosphere (From Thompson and Tracy)

ALLOY	Minutes to Break Under Stress of 10,000 psi
Copper.....	No failure in 40,000 min.
90/10 Cupronickel.....	9552
80/20 Cupronickel.....	13527
70/30 Cupronickel.....	No failure in 40,000 min.
90/10 Copper Zinc.....	973
70/30 Copper Zinc.....	254

On the basis of theoretical considerations involving the nature of the electron configuration of the atom and supported by data on corrosion in some environments, Uhlig⁸ concluded that copper-nickel alloys would demonstrate characteristics of passivity when the nickel content exceeded 40 percent. Thus, the alloys that contain 30 percent or less nickel with which we are concerned here lie below the critical

limit for passivity and should rarely demonstrate the kind of behavior typical of passive compositions. Such behavior includes highly localized attack—pitting—which is usually undesirable and, therefore, the 10 percent to 30 percent nickel alloys benefit from this favorable aspect of their fundamental composition effects.

Not immediately related to the mechanisms just described are effects on corrosion resistance which appear to reflect more directly the influence of a powerful corrosion resisting characteristic of nickel as compared with copper. For example, nickel is much more resistant than copper to corrosion by strong alkalis. It might be expected that the nickel copper alloys would reflect this property roughly in proportion to the nickel content of the alloy. That this is actually the case is shown by the data in Figure 2 based on tests in 50 percent caustic soda.

Similarly, nickel is superior to copper in resisting corrosion by solutions of ammonium hydroxide. As a result, attack of copper nickel alloys by ammonium hydroxide solutions would be expected to decrease with increasing nickel content as indeed it does as shown by the data from Skortcheletti and Idelchik⁹ plotted in Figure 3. A similar trend was shown in tests by Rawdon and Groesbeck¹⁰ which involved exposure to one normal ammonium hydroxide at 30 degrees C (86 degrees F). In the unaerated solution copper was corroded at a rate of 197 mdd, nickel at a rate of 1 mdd and 29 percent nickel alloy at a rate of 1.3 mdd. Aeration increased the rate for copper to 574 mdd, but did not increase the corrosion of nickel or the 29 percent nickel alloy above the rates observed in the unaerated solution.

Studies of stress corrosion cracking susceptibilities regularly make use of ammonia or ammonia vapor as the specific corroding and cracking agent. Such investigations regularly show that the cupronickel alloys are superior to copper and other copper base alloys in resisting both corrosion and cracking¹¹ in vapors containing ammonia.

Some comparative data taken from the work of Thompson and Tracy are shown in Table 1 based on exposure of the alloys under tensile stress in a moist ammoniacal atmosphere. The authors noted that the 30 percent nickel alloy corroded at a very low rate—the samples were hardly tarnished at the end of a week. Of the alloying elements studied, nickel was ranked as having the least unit cracking tendency and also least in intergranular penetration in the absence of stress.

The 70/30 cupronickel alloy tubing was tested by Bulow with residual stresses resulting from cold drawing (50 percent) in an ammoniacal atmosphere using a technique described in his paper before the American Society for Testing Materials.¹² His data comparing red brass and 70/30 cupro nickel are plotted in Figure 4. They confirm the results of Thompson and Tracy with respect both to cracking tendencies and corrosion resistance. The coincidence between the loss in strength and loss in weight of cupronickel alloys is evidence of freedom from intergranular attack.

The advantage of cupronickel alloys with respect to resisting corrosion by ammonia is of practical importance where the concentration of ammonia is low—as in steam contaminated with ammonia, such as may be encountered for example in vapors from sugar liquors used for heating in multiple effect evaporators. Comparative tests in ammonia vapors were carried out by C. Breckon¹³ and his associates in the laboratories of The Yorkshire Copper & Brass Company, Leeds, England. Vapors from a boiling solution that contained 0.4 percent by weight ammonia were allowed to condense in tubes of the alloys under test. The extent of corrosion was determined by analysis of the copper contents of the condensates. Under such conditions, it was found that aluminum brass (21% zinc, 2% aluminum), Admiralty Brass and Yellow Brass (70% copper, 30% zinc) were corroded at about the same rate which was 20 times that of a cupronickel alloy that contained 10 percent nickel and 400 times that of a cupronickel alloy that contained 30 percent nickel. Similar tests with other concentrations of ammonia showed that with higher concentrations the differences among the alloys became narrower, while with lower concentrations the superiority of the cupronickels over the brasses became greater.

In some environments, both nickel and copper are subject to severe attack so that no advantage can be anticipated from the addition of nickel to copper. An example of this is provided by behavior in contact with hydrogen sulfide and other sulfur compounds at elevated temperatures where the cupronickel alloys under discussion are subject to rapid corrosion. This does not extend, however, to hydrogen sulfide etc. encountered in various solutions at lower temperatures, e.g. polluted salt water in which the cupronickel alloys regularly demonstrate excellent resistance to attack^{2,3,4,5} depending upon type and extent of pollution.

Performance in Specific Services

During the past twenty years specimens of the cupronickel alloys have been included in several hundred tests carried out by exposing specimens in various types of operating equipment, particularly in the chemical and process industries. This has yielded a large mass of miscellaneous data pertaining to specific conditions. It would be impractical to include all these data in a paper such as this. Instead, appropriate selections will be offered to provide a picture of how these alloys can be expected to perform in some typical environments. The remaining data can be applied to other specific problems most readily by direct communication with the author.

The specimens used for these field tests were of commercial production and contained the usual amounts of other elements. Of these, the most important corrosion-wise was iron which was added to the cupronickel alloys to enhance their resistance to corrosion and erosion by salt water. In the case of the 30 percent nickel alloy, the desired range of

iron content was specified at one time to be between 0.25 percent and 0.60 percent. Currently, the preferred range is 0.40 percent to 0.70 percent iron. With the 10 percent nickel alloy two iron contents have been favored—one around 0.8 percent and one around 1.5 percent. Current specifications permit a range in iron from 0.50 percent to 2 percent, while the U. S. Navy specification calls for iron from 1.0 percent to 1.75 percent.^{14, 15}

The iron normally present in both the 70/30 and 90/10 cupronickel alloys is within the range of solid solubility after commercial annealing treatments. Thus, it would not be expected to have any effect in promoting localized attack.

As mentioned previously, iron reduces corrosion in salt water and might reasonably be expected to have a similar effect in other brines. Tests in miscellaneous media in which specimens of high and low iron content 70/30 cupronickel have been included have shown no significant difference between the two alloys. The high iron variety is the one likely to be provided. Therefore, the data to be presented here were secured by exposing specimens of this type. Analyses of typical lots of cupronickel used in these studies are given in Table 2.

Waters Other Than Salt Waters

From time to time, specimens have been exposed in various waters, including types that might be used for cooling purposes. Results of such tests have been assembled in Table 3.

As mentioned previously, the cupronickel alloys are used regularly as tubes in boiler feedwater systems. Their ability to withstand corrosion in this service has been demonstrated more by their good

performance in many installations than by results of quantitative corrosion tests. L. F. Collins¹⁶ included 80/20 and 70/30 cupronickel specimens in a study of corrosion in boiler feedwater treating systems. Specimens were exposed to water at 120-150 degrees F for 65 days. The water was saturated with oxygen and contained 1 to 4 ppm CO₂ at a pH of 7.4 to 7.8. The cupronickel alloys suffered negligible corrosion, while copper and various brasses were corroded at rates from 3 to 4 mils per year.

Some data on corrosion by steam condensate from turbines at high temperatures were provided by tests carried out by Ristoph and Powell.¹⁷ These investigators were concerned primarily with the amounts of metals that might be picked up by condensate as a result of contact with the alloys as they might be used in boiler feedwater heaters. From their observations, it was calculated that a 70/30 cupronickel alloy might be corroded at a maximum rate of about 1.5 mils per year which was about half the rate calculated for Admiralty Brass.

TABLE 4—Results of Tests in Boiler Feedwater Heater

Temperature.....	388°F
Pressure.....	1000 psi
Duration.....	64 Days
Character of Water.....	pH 8 to 8.5 Oxygen 0.03 to 0.06 cc./liter Ammonia 0.02 ppm CO ₂ Zero
MATERIAL	Corrosion Rates in Mils Per Year
80/20 Cupronickel.....	0.1
70/30 Cupronickel.....	0.2
Copper.....	0.1
Admiralty Brass.....	0.07
Monel.....	0.09

TABLE 2—Analyses of Typical Lots of Cupronickel Alloys Used in Corrosion Studies

ALLOY	COMPOSITION—PER CENT				
	Cu	Ni	Fe	Mn	Zn
70/30 Cupronickel.....	69.3	29.8	0.4	0.5	0.0
90/10 Cupronickel.....	89.1	9.8	0.7	0.2	0.2

TABLE 5—Results of Tests in Stripping Column Handling Monoethanolamine Plus Hydrogen Sulfide

ALLOY	Corrosion Rates in Mils Per Year	
	Bottom 230°F	Middle 200°F
70/30 Cupronickel.....	8	38
Admiralty Brass.....	11	2
Red Brass.....	107	149

TABLE 3—Results of Tests in Miscellaneous Waters

Conditions of Exposure	Duration—Days	Corrosion Rates in Mils per Year					Remarks
		90/10 Cu-Ni	70/30 Cu-Ni	Copper	Admiralty Brass	Red Brass	
1. In water at bottom of spray chamber in air conditioning system, pH 7 and treated with chromate.....	590	..	0.001	0.002	0.003	..	No Pitting
2. In water side of tubular cooler, pH 7.8 alkalinity as CaCO ₃ , 165 ppm, temperature 150° F.....	40	..	3	4	5	..	No Pitting
3. In inlet of condenser water box using water from Potomac River at Hagerstown, Md.....	394	..	2	....	2	..	Admiralty Pitted to 7 mils
4. In lock tunnel on Allegheny River at Pittsburgh, Pa.....	330	..	0.3	....	....	..	Pitted to 1 mil
5. In lock tunnel of Monongahela River at Monessen, Pa.....	338	..	5	....	....	..	No Pitting
6. In outlet of condenser water box using acid water pH 5, sometimes as low as 3, from Monongahela River.....	240	6	8	4	5	0.7	No Pitting
7. In Mississippi River, Bayou Bodcau Dam, La.....	495	..	0.3	....	....	..	No Pitting
8. In open condenser water box using water from St. Lawrence River at Montreal, Quebec. 40° to 170° F.....	440	..	0.5	....	0.6	..	No Pitting
9. In filter for well water high in free CO ₂ —cold.....	630	..	1	1	1	1	No Pitting
10. In hot water storage tank, same water as No. 9, 150° F.....	630	..	1	0.3	Dezincified	0.5	No Pitting
11. In open tank handling well water containing 85 ppm CO ₂ , 65 ppm H ₂ S, 120 pp. NaCl.....	104	..	1	2	0.1	..	No Pitting
12. In hot water heater handling Pittsburgh City water at 140° F.....	1422	..	0.3	0.2	....	..	Pitting—both to 3 mils
13. In hot water heater handling well water containing free CO ₂ at Hollis, L. I. at 160° F.....	1555	..	0.3	0.2	5	0.3	Admiralty Brass dezincified, Red Brass, Copper and Cu-Ni pitted to 3 mils.
14. In hot water heater handling Catskill water at Kingston, N.Y. at 140° F.....	454	..	0.01	No Pitting

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Some quantitative data were secured more directly by exposing specimens for 64 days at the outlet side of a feedwater heater operated at 1000 psi pressure at 388 degrees F. The water was treated to a pH of 8 to 8.5. The oxygen content was from 0.03 to 0.06 cc per liter, ammonia 0.02 ppm and CO₂ practically zero. The rates of corrosion observed are shown in Table 4.

Ammoniacal Solutions

As mentioned previously, the cupronickel alloys are superior to other copper base alloys in resisting attack by ammonia and ammoniacal compounds.

Resistance to amine solutions as used for scrubbing gases depends a great deal on what else is present. Where conditions are strongly reducing, resistance to corrosion is quite good. For example, specimens of 70/30 cupronickel exposed for 100 days in a monoethanolamine stripping tower in a plant used for removing carbon dioxide from hydrogen at 180 to 220 degrees F were corroded at a rate of only 1.9 mils per year with no pitting. The monoethanolamine itself can be quite corrosive to 70/30 cupronickel in the presence of oxygen. In a 5-day laboratory test in an aerated 15 percent solution at 140 degrees F the rate of attack was 250 mils per year.

Hydrogen sulfide will also accelerate attack by monoethanolamine as demonstrated by tests in a stripping tower reported by Wilten.¹⁸ Illustrative data are shown in Table 5. Similar high rates of attack for 70/30 cupronickel were observed in a gas water separator on a diethanolamine reactivator in a Gerbitol plant. Specimens of copper and 70/30 cupronickel were destroyed during a 230-day test at 75 degrees F. The solution was reported to contain H₂S, CO₂, HCN, HCNS, NH₃ and NH₄OH. A similar fate befell specimens exposed for 483 days opposite the reboiler inlet in a reactivator tower handling at 228 degrees F a solution which contained 11-15 percent diethanolamine and 10-50 grains H₂S per gallon.

Reference has been made already to the good behavior of the cupronickel alloys in resisting low concentrations of ammonia present as a non-condensable gas in contaminated steam. Specimens of 70/30 cupronickel were exposed for 130 days in a stream of non-condensable gases from a vacuum pump on an evaporator used to concentrate sugar beet pulp water. The indicated rate of corrosion was only 0.07 mil per year.

Corrosion by ammonia in non-condensable gases is sometimes encountered in sugar liquor evaporators in which the steam used for heating comes from preceding effects. Attack is generally localized in the form of a groove on the steam side of the tube just below the top tube sheet. Substitution of 90/10 cupronickel for the yellow brass ordinarily used in this service has eliminated failures from this



90/10
cupronickel

yellow brass

Figure 5—Sections of tubes corroded by non-condensable gases below tube sheets in sugar liquor evaporator. X 10.

source as described in a paper by H. G. P. Tyrer and A. P. Richardson.¹⁹ The advantage of the cupronickel alloy over yellow brass is demonstrated clearly by Figure 5 which shows longitudinal sections of tubes from a point just below the top tube sheet.

Brines

As might be anticipated from the good behavior of cupronickel alloys in salt water, they also demonstrate excellent resistance to corrosion by brines as

TABLE 6—Results of Corrosion Tests in Brines

Conditions of Test	Duration—Days	RATES OF CORROSION IN MILS PER YEAR				Remarks
		90/10 Cu-Ni	70/30 Cu-Ni	Copper	Admiralty Brass	
Above Top Tube Sheet of Salt Evaporator, pH 8.0 to 8.5 at 212°F.....	149	6	4	12	7	No Pitting
Above Top Tube Sheet of Salt Evaporator at 205°F.....	216	3	2	4	4	No Pitting
In Bottom of Bittern Boil Down Tank 23 to 29 Percent CaCl ₂ 7 to 8.7 Percent MgCl ₂ 1.5 to 2.2 Percent NaCl Free Chlorine 0.025 Percent Temperature 240-250°F.....	70	..	52	63	41	No Pitting
Mixture of 100 gpl CaCl ₂ and 100 gpl NaCl in wier box at 131°F.....	107	..	4	9	..	No Pitting
In vapors above CaCl ₂ Open Evaporator at 350°F.....	45	..	49	102	..	No Pitting
In Crystallizer for BaCl ₂ 30 to 40 Percent, pH 7.0 to 8.0 at 300°F.....	35	..	8	..	..	No Pitting
In KCl Dissolving Tank at 122°F.....	29	..	0.6	2	..	No Pitting

they are encountered in salt plants, etc. Some illustrative data have been assembled in Table 6.

Alkaline Solutions

The resistance of cupronickel alloys to attack by strong alkalis is determined principally by the nickel content as illustrated by Figure 1. Resistance extends to even more concentrated solutions, but not

TABLE 7—Results of Tests of Cupronickel Alloys in Concentrated Caustic Soda

Range of Concentration Percent NaOH	Temperature Degrees F	Corrosion Rates in Mils Per Year		
		Copper	80/20 Cu-Ni	70/30 Cu-Ni
60-75.....	300-350	41	6	4
60-100.....	300-500	92	21	21
100.....	750	786	756	692

TABLE 8—Results of Tests in Alkaline Solutions Containing Sulfur Compounds

Conditions of Exposure	Duration—Days	RATES OF CORROSION IN MILS PER YEAR			Remarks
		70/30 Cu-Ni	Copper	Admiralty Brass	
1. In open tank used to boil 18-22 Percent NaOH to release mercaptans at 175°F.....	30	1	..	..	No Pitting
2. In reboiler of caustic stripper, 1-2 Percent NaOH, 3 percent Na ₂ S, 10 percent sodium phenolate + 0.7 mg. per liter as sodium mercaptides at 255°F.....	131	25	..	..	Pitted to 3 mils
3. In 10 percent sodium sulfide in storage tank at atmospheric temperature.....	81	1	..	1	No Pitting
4. In 60 percent sodium sulfide in flaker feed tank at 340°F.....	28	14	..	18	No Pitting
5. In regenerator reboiler for steam stripping of mercaptans from solutizer solution 25.2 percent potassium hydroxide 37.8 percent potassium isobutyrate 5.5 percent potassium sulfide 1.9 percent potassium mercaptides 2.1 percent potassium carbonate at 286°F.....	140	15	..	..	No Pitting
6. In vapors from solution in item 5.....	140	12	..	..	No Pitting

TABLE 9—Results of Tests in Petroleum Products Containing Hydrogen Sulfide

Arranged in Order of Increasing Temperature

Conditions of Exposure	Duration—Days	Corrosion Rates in Mils per Year			Remarks
		90/10 Cu-Ni	70/30 Cu-Ni	Admiralty Brass	
1. Hydrocarbons containing 2.5% H ₂ S, 35% H ₂ , pH 8 at 90-110° F. in bottom section of gas compressor water knockout drum.....	640	..	10	0.4	No Pitting
2. Hydrocarbons containing H ₂ S and water in accumulator for main fractionator cat cracker, 90-140° F.....	640	..	5	0.1	No Pitting
3. Hydrocarbons containing H ₂ S, N ₂ , CO, CO ₂ + water in outlet from main fractionator condensers of cat cracker at 90-145° F.....	640	..	4	0.2	No Pitting
4. Hydrocarbons containing less than 1.5% H ₂ S + water in bottom section of debutanizer accumulator at 100-145° F.....	640	..	Destroyed	0.1	No Pitting
5. Overhead product containing 2450 grains H ₂ S per 100 cu. ft. on top tray of debutanizer tower at 160-170° F.....	260	..	3	....	No Pitting
6. In stripper column overhead condenser vapor space, approximately 0.1% sulfur in West Texas Crude at 145-185° F.....	158	..	8	0.1	No Pitting
7. In vapors containing H ₂ S and ammonia + traces of formic acid in vapor nozzle between overhead condensers in cat cracking unit at 170-210° F.....	300	..	6	0.5	No Pitting
8. Crude oil containing 0.34% S at top of crude flash tower at 220-240° F.....	43	..	21	....	No Pitting
9. Vapors from primary distillation of crude oil containing H ₂ S, HCl and SO ₃ on top tray of fractionating tower at 218-258° F. Ammonia added to hold pH of water to 8.5.....	206	..	9	....	No Pitting
10. In liquid on top tray as per item 9.....	208	..	5	....	Pitted to 10 mils
11. In water containing trace of H ₂ S, pH 8 in bottom section of absorber water knockout drum at 220-260° F.....	640	..	Destroyed	....	.....
12. In hydrocarbons and water containing less than 1% H ₂ S, N ₂ , CO, CO ₂ , 1.5% H ₂ in overhead vapor line from main fractionator of cat cracker at 260-290° F.....	640	..	1	0.3	No Pitting
13. Mercaptan sulfur in depropanizer in seal pan in depropanizer tower at 275-290° F.....	490	..	0.2	0.1	No Pitting
14. Stripping of natural gasoline from West Texas Crude and containing 0.1% S + ammonia to hold pH at 7.0 to 8.0 in overhead condenser of stripper column at 290-295° F.....	109	74	15	1	No Pitting
15. In vapors from primary distillation of crude oil + H ₂ S, HCl and NH ₄ Cl on 3rd tray of crude fractionator at 275-325° F.....	70	..	5	....	No Pitting
16. Stripping of natural gasoline from West Texas Crude containing 0.1% S as in item 14 in vapor space of stripper column overhead condenser at 260-330° F.....	109	Destroyed	Destroyed	2	No Pitting
17. Hydrocarbon liquid & vapors in atmospheric distillation of crude oil containing 5 to 10 gr. H ₂ S and 10 gr. HCl per barrel at 265-335° F.....	329	..	9	Destroyed	No Pitting
18. Hydrocarbon liquid & vapors in atmospheric distillation of crude oil containing 10 gr. HCl and 5-10 gr. H ₂ S per barrel on top tray of distilling unit at 265-335° F.....	329	..	10	20	Admiralty Perforated
19. In condensing vapors containing water, H ₂ S, mercaptan S and fixed gases in fractionation unit overhead condenser at 268-378° F.....	189	..	8	3	No Pitting
20. Hydrocarbon vapors & steam containing H ₂ S on top tray of light gas oil stripper at 440-460° F.....	260	..	Destroyed	0.6	No Pitting
21. In crude oil cracking unit bubble tower at 640° F.....	71	..	83	1	No Pitting
22. In hydrocarbon liquid & vapors containing organic acids and H ₂ S in evaporator tower of light oil cracking unit at 720° F.....	53	..	Destroyed	....	.....

to fused caustic as shown by laboratory tests over three ranges of concentration as summarized in Table 7.

The 70/30 cupronickel alloy has been used successfully as tubes in evaporators for concentrating caustic soda to about 50 percent where copper pickup by the caustic could be tolerated.

The ability to resist alkaline attack is also useful in processes involving treatment of other chemicals with caustic soda for neutralization or other reactions. For example, in the treatment of lignosulfonic acids with caustic soda in the manufacture of vanillin, specimens of 70/30 cupronickel exposed in an evaporator at 212 degrees F for 502 hours were corroded at a rate of only 0.4 mil per year where copper specimens were corroded at a rate of 19 mils per year. Similarly, in an agitator for treating oil with lye, specimens of 70/30 cupronickel were corroded at a rate of only 0.1 mil per year in a 37-day test.

While corrosion by caustic solutions may be aggravated by the presence of sulfur compounds, the cupronickel alloys are able to resist attack under many conditions. Some illustrative data are shown in Table 8.

Petroleum Products Containing Hydrogen Sulfide

So far as cupronickel alloys are concerned, the presence of hydrogen sulfide and the temperature

TABLE 10—Results of Tests in Miscellaneous Petroleum Refinery Environments

Conditions of Exposure	Duration—Days	Corrosion Rates in Mils per Year				Remarks
		90/10 Cu-Ni	70/30 Cu-Ni	Copper	Admiralty Brass	
1. In vapors from lubricating oil containing HCl and organic acids in vapor line from shell still at 700° F.	10	..	228	..	372	Admiralty Perforated
2. In look box of still processing re-run acid treated naphtha containing SO ₂ , SO ₃ and some ammonia at 120° F.	33	..	20	..	....	No Pitting
3. In water containing 10% phenol + 50-1320 ppm chlorides in phenol recovery tower at 220° F.	70	..	17	32	....	No Pitting
4. In vapor phase of Item 3 at 220° F.	70	..	3	3	....	No Pitting
5. In non-condensable gases & condensate of light gas oil & steam containing some HCl in condensate line at 90-120° F.	50	..	0.5	..	0.9	No Pitting
6. In fractionating tower in top tray subject to splashing from reflux at 185° F.—East Texas Crude.	120	..	17	..	87	No Pitting
7. In cracked gasoline distillate in depropanizer reboiler at 300-335° F.	123	..	4	..	2	No Pitting
8. In straight run gasoline distillate at top of tower exposed to vapors & reflux at 195-219° F.	156	20	10	..	Destroyed	No Pitting
9. In mixture of crude oil & sulfuric acid in agitator at atmospheric temperature	20	..	0.2	..	....	No Pitting
10. In mixture of 65% sulfuric acid & hydrocarbons at 90-110° F.	....	..	3	..	....	No Pitting
11. In hydrocarbon mixed with 1% sulfuric acid & 0.3% water immersed in alkylator at 180-250° F.	30	..	6	..	....	No Pitting
12. In mixture of 15% by volume Stoddards solvent and 85% sulfuric acid at 75° F.	1	..	8	..	....	No Pitting
13. Low end point gasoline containing HCl in top reflux tray in tower at 140-255° F.	116	24	6	..	7	No Pitting
14. High end point gasoline containing HCl and H ₂ S in bottom of run tank at 178° F.	216	39	9	..	3	No Pitting
15. In vapor line of first gasoline condenser at 400-450° F.	290	..	1	..	4	No Pitting
16. Sweet gasoline vapor in shell side of condenser at 350° F.	365	..	0.4	..	0.3	No Pitting
17. Tubes in crude oil gasoline heat exchanger at 300-80° F.—data from measurements of tubes.	1825	..	3	..	....	No Pitting
18. In 90-95% hydrofluoric acid and 5-10% isobutane at top of acid regeneration tower at 240-300° F.	70	..	1	82	....	No Pitting
19. In hydrofluoric acid water and hydrocarbons at inlet side of preheater at 90-135° F.	111	..	1	19	....	No Pitting
20. At outlet side of preheater in Item 19 at 150-260° F.	111	..	6	Dest.	....	No Pitting
21. In 10% hydrofluoric acid and 90% light hydrocarbons in stripper tower at 100-150° F.	117	..	1	3	....	No Pitting
22. In 80% hydrofluoric acid + 1% water and organic polymers in hydrofluoric acid feed line between preheater and regeneration tower at 270-290° F.	102	Dest.	Dest.	Dest.	....	....

TABLE 11—Results of Tests in Various Organic Compounds

Conditions of Exposure	Duration—Days	Corrosion Rates in Mils per Year				Remarks
		90/10 Cu-Ni	70/30 Cu-Ni	Copper	Admiralty Brass	
1. In benzene toluol and xylol in light oil decanter in coke by-product plant at 50-120° F.	45	2	0.5	6	....	Copper pitted to 19 mils
2. In same process as Item 1 in vapor section of cooler at 190-210° F.	46	2	1	26	....	No Pitting
3. In benzene toluene, etc. + ammonium salts of sulfonated compounds sulfated acids, SO ₂ & ammonia at pH 4—tested as tubes in still at 330° F.	300	..	42	..	....	No Pitting
4. In condensed vapors of benzol, toluol, xylol, thiophene, hydrogen sulfide, sulfur dioxide, oxygen and water in light oil condenser at 113° F.	27	..	61	74	55	No Pitting
5. In vapors of Item 4 at inlet to condenser at 210° F.	27	..	8	14	10	No Pitting
6. In impure 10% citric acid containing some chlorides in storage tank at 125° F.	36	..	29	24	....	No Pitting
7. In 37% formaldehyde containing 0.08 to 0.20% formic acid in exit chamber of heat exchanger on absorption tower at 110° F.	30	..	8	10	....	No Pitting
8. Propionic and heavier acids in acetic acid recovery column at 300° F.	21	..	67	108	....	No Pitting
9. In vapors above light sugar solutions, pH 4.3 to 5.2 at 140° F.	365	2	0.4	1	1	Brass slightly pitted
10. In vapors from boiling of low grade sugar syrup in vacuum pan at 150° F.	365	..	0.7	0.6	....	No Pitting
11. In vapors from boiling white sugar in vacuum pan at 158° F.	365	..	0.06	0.06	....	Copper suffered wide very shallow pitting
12. In sugar cane juice evaporator cleaned with HCl and caustic soda at 150-180° F.	55	..	0.5	0.4	....	No Pitting
13. In evaporator for carbonated beet sugar juice, pH 8.2 above juice level at 220° F.	82	..	0.06	0.1	....	No Pitting
14. Below juice level in Item 13.	82	..	1	2	....	No Pitting
15. In 57% pure tartaric acid in vacuum evaporator at 130° F.	10	..	7	15	....	No Pitting
16. In glutamic acid & sodium chloride, pH 3.2, aerated in crystallizer at 77° F.	28	..	6	..	5	No Pitting
17. In crude glutamic acid, pH 5.6 in vapors in evaporator at 160° F.	36	..	3	..	4	No Pitting
18. In evaporator concentrating lactic acid from 10 to 22% at 130° F.	15	..	57	49	....	No Pitting
19. In crude glycerine evaporator, pH 4 at 230° F.	3	..	6	9	....	No Pitting

TABLE 12—Results of Tests in Chlorinated Hydrocarbons

Conditions of Exposure	Duration Days	Rates of Corrosion in Mils Per Year		Remarks
		70/30 Cu-Ni	Copper	
In Inlet of condenser from Chlorobenzene Distillation Unit at 210°-360° F.	4	1	2	No Pitting
In 2,4 Dichlorophenol at Top of Packing in Distillation Column at 265°-300° F.	21	5	10	No Pitting
Immersed in Wet Ethylene Dichloride at 185° F.	28	0.2	..	No Pitting

reached by the metal are the principal factors determining the extent of corrosion. Performance is generally good even in the presence of H₂S at

moderate temperatures, but at elevated temperatures severe attack will occur. It is difficult to establish a critical temperature for the incidence of severe attack but, as indicated by the test results assembled in Table 9, it may be assumed that severe attack by H₂S will occur at temperatures over 400 degrees F for the 30 percent nickel alloy and over 300 degrees F for the 10 percent nickel alloy. Below these temperatures performance of the cupronickel alloys will generally be fair to good, but usually inferior to that of the high zinc brasses, such as Admiralty Brass. There may be exceptions, as in Items 17 and 18 of Table 9 where, evidently, the presence of HCl resulted in more severe attack of the brass.

TABLE 13—Results of Tests in Sulfuric Acid and Salts

Conditions of Exposure	Duration—Days	Corrosion Rates in Mills per Year				Remarks
		90/10 Cu-Ni	70/30 Cu-Ni	Copper	Admiralty Brass	
1. Immersed in aerated 1% sulfuric acid at 70° F.	15	15	16	25	....	No Pitting
2. Immersed in aerated 4.2% sulfuric acid at atmospheric temperature.	2	28	23	28	....	No Pitting
3. Immersed in aerated 5% sulfuric acid at 86° F.	1	..	33	40	....	No Pitting
4. Immersed in steel pickling tank in inhibited sulfuric acid—about 5% at 150 to 170° F.	13	..	96	99	....	No Pitting
5. In corn starch converter acidified with 0.05 N sulfuric acid at 222° F. in liquid phase.	10	..	33	76	....	No Pitting
6. In corn starch converter acidified with 0.05 N sulfuric acid at 222° F. in vapor phase.	10	..	10	8	....	No Pitting
7. In evaporator concentrating sodium aluminum sulfate from 20% to 60% in liquid phase at 244° F.	13	..	8	6	....	No Pitting
8. In evaporator concentrating sodium aluminum sulfate from 20% to 60% in vapor phase at 244° F.	13	..	62	97	....	No Pitting

TABLE 14—Results of Tests in Halogens and Halogen Compounds

Conditions of Exposure	Duration—Days	Corrosion Rates in Mills per Year				Remarks
		90/10 Cu-Ni	70/30 Cu-Ni	Copper	Admiralty Brass	
1. In scrubber with lime water spray handling furnace gas containing fluorine entering at 950° F.	18	..	63	186	....	No Pitting
2. Partially immersed in 38% hydrofluoric acid at 230° F.	2	..	36	47	....	No Pitting
3. Partially immersed in 98% hydrofluoric acid at 100° F.	3	..	2	6	....	No Pitting
4. Immersed in 32% fluoroboric acid + 1.5% boric acid in storage tank at 75° F.	30	2	1	2	....	No Pitting
5. In solution containing 85 gpl sodium acid fluoride, 30 gpl hydrofluoric acid + crystals of sodium acid fluoride in reaction tank at 175° F.	30	128	111	..	....	No Pitting
6. In hydrofluosilicic acid from 0.5 to 25% in exit of absorption tower at 115° F.	30	..	3	4	....	No Pitting
7. In aerated 1% hydrochloric acid at 70° F.	15	55	46	150	....	No Pitting
8. In aerated 10% hydrochloric acid at 70° F.	2	147	130	132	....	No Pitting
9. In corn starch converter with 0.003 N hydrochloric acid at 280° F.	14	..	3	4	....	No Pitting
10. In corn starch converter neutralizer, 0.033 N hydrochloric acid neutralized to pH 4.5 with sodium carbonate at 212° F.	22	..	5	8	....	No Pitting
11. In sodium hypochlorite solution containing 4 to 9 gpl available chlorine at atmospheric temperature in surge tank.	55	..	7	..	....	Irregular Shallow Pits

TABLE 15
Results of Tests in Pulp and Paper Stock Suspensions

Conditions of Exposure	Duration Days	Corrosion Rates in Mills Per Year		
		80/40 Cu-Ni	70/30 Cu-Ni	Phosphor Bronze
1. In mixed groundwood and sulfite pulp in paper machine headbox at 70-85°F.	147	..	4	5
2. In newsprint stock in headbox, pH 5 at 85-110°F.	160	..	1	20
3. In mixed groundwood and sulfite pulp in decker headbox, pH 3.8 to 4.1 at 95°F.	52	15	14	17
4. In sulfite white water in pit of Fourdrinier, pH 3.0 to 3.3 at 80°F.	184	..	4	5
5. In sulfate stock in wire pit, pH 4 to 6.5 at 65°F.	503	..	1	1
6. In groundwood white water in seal pit of vacuum decker, pH 4.6 at 112°F.	52	9	8	11

While, as indicated, resistance to corrosion by sulfur compounds on the vapor side would not call for the use of cupronickels, there may be instances where better performance on the cooling water side would justify the choice of the cupronickels in preference to brasses. The cooling effect of the water will often hold metal wall temperatures on the vapor side to a level where attack of the cupronickels by sulfur compounds will be tolerable.

Miscellaneous Petroleum Products

The data presented in Table 9 and the pertinent discussion referred only to services in petroleum refineries where hydrogen sulfide exerted a controlling effect on corrosion of the cupronickels. The picture is extended to other environments by the data assembled in Table 10.

Organic Compounds

As might be expected, the cupronickel alloys offer good resistance to attack by various organic compounds other than petroleum products. Some miscellaneous data have been assembled in Table 11 to illustrate the order of resistance that may be anticipated.

Chlorinated Solvents

Ordinarily, the cupronickels can be expected to demonstrate good resistance to attack by chlorinated solvents as indicated by the data assembled in Table 12. However, there may be exceptions in the case of carbon tetrachloride. In a particular test, specimens of 70/30 cupronickel partially immersed in a boiling mixture of carbon tetrachloride and distilled water were corroded at the amazingly high rate of 850 mils per year. The specimens were cut through at the top of the water layer in 63 hours. This may well have been due to the auto-accelerative effects of the copper chloride that accumulated in the water layer as corrosion proceeded. Similarly high rates of attack might not be encountered in the absence of a substantial water layer and where similar opportunity for accumulation of corrosive corrosion products would not exist. However, this result indicates the conditions that should be avoided.

Sulfuric Acid

As might be anticipated, the cupronickels resist sulfuric acid very well. Some pertinent data have been included already in the tables that refer to petroleum refinery services. Some additional information covering simple sulfuric acid solutions and this acid and its salts as encountered in industrial processes has been assembled in Table 13. As is the case

with copper and other copper base alloys, corrosion is accelerated by aeration and the presence of other oxidizing agents and best performance is secured under reducing conditions.

Halogens And Halogen Compounds

A limited amount of data on the behavior of cupronickels in halogens and their compounds—other than brines covered by Table 6—have been assembled in Table 14.

Paper Stock Suspensions

There has been considerable interest in the use of cupronickel alloys in the form of centrifugal castings for perforated rolls on Fourdrinier paper machines. The desired advantages were greater strength and especially stiffness or rigidity due to the higher modulus of elasticity of the nickel alloys as compared with the bronzes ordinarily used. A high resistance to corrosion and erosion is also required. Data pertinent to this latter feature have been assembled in Table 15.

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DISCUSSION

Question by John H. Naschke, Humble Oil & Refining Co., Houston:

What maximum or tolerable concentration, in parts ammonia per million parts water is practical in contact with Admiralty Brass and in contact with 80/20 cupronickel?

Question by H. Howard Bennett, Socony Vacuum Oil Co., Inc., Paulsboro, N. J.:

In an environment such as boiler feedwater, what is the effect of ammonia in concentrations up to 10 to 15 ppm on the corrosion rates of brasses and copper-nickel alloys?

Reply by F. L. LaQue:

The amount of ammonia that can be tolerated without excessive corrosion of copper and brasses is influenced principally by the amount of oxygen that may be present with the ammonia and by the temperature of the condensate in which the ammonia would exist. In the absence of oxygen some have suggested that the tolerable concentration is about 50 ppm while others have indicated that the pH should not exceed about 9.6. In the petroleum industry where ammonia has been used in neutralizing the acidity to reduce corrosion of iron the critical pH range of the condensate has been indicated as being around 8 to 8.5. There are data in the paper which should indicate considerable advantage of the copper-nickel alloys over the brasses in resisting attack by wet ammonia vapors. These alloys can, therefore, be considered to be more reliable than the brasses where there is a danger in service of encountering what might be called excessive amounts of ammonia.

Questions by A. Orman Fisher, Monsanto Chemical Co., St. Louis:

Describe briefly the laboratory apparatus and methods used for studying the effects of velocity upon corrosion rates? How do the results correlate with field data?

Reply by F. L. LaQue:

A description of the technique regularly used for studying the abilities of materials to resist erosion by sea water may be found in a paper by F. L. LaQue and W. C. Stewart, "Some Methods for Studying the Behavior of Alloys in Sea Water at High Velocity" which was published in *Metaux et Corrosion*, **23**, No. 274, 147 (1948). The results of these erosion tests as carried out under circumstances appropriate to the service to be encountered are quite consistent with service behavior. At least they provide a reliable basis for choosing the proper compositions of alloys for particular service although a good deal of discretion and experience are required in using the laboratory data to estimate the actual life of a material in service.

Question by Paul J. Gegner, Columbia-Southern Chemical Corp., Barberton, Ohio:

Please comment on the effects of small amounts of iron on the corrosion resistance of copper alloys.

Reply by F. L. LaQue:

Iron is included in the 90/10 and 70/30 cupronickel alloys primarily for the purpose of improving their resistance to impingement attack and other forms of erosion by salt water. These effects have been discussed in detail in several papers including those in References 2 and 4 in this paper. The iron exists in these alloys in solid solution and does not appear to have any considerable effect on the resistance to corrosion by acids and alkalis. As is the case with salt water, the improved erosion resistance can be expected to extend to other brines and neutral and alkaline salt solutions.

Materials used for specimens in the several corrosion tests from which data were reported in the paper were commercial alloys which contain the usual amounts of iron, as mentioned in the paper.

Extrinsic Line Current Fluctuations Seriously Restrict Progress of Coating Conductance Surveys on Large Trunk Line*

By G. I. RUSSELL* and L. B. NELSON**

LINE CURRENTS of unknown source varying from as high as 20 amperes in one direction to the same value in the opposite direction within minutes have been measured and recorded on the 24-inch trunk line of the Trans-Mountain Oil Pipe Line Company. Since the line currents were almost constantly fluctuating it was necessary to average from 20 to 30 measurements to obtain a measurement of desired accuracy during the coating conductance surveys.

Pipe-to-soil potentials referred to a copper-copper sulfate half cell measured at points along the pipe line varied between 1.9 volts negative and 1.5 volts positive. A variation of as much as 3 volts was noted in one half a minute. The line current oscillations during certain periods were violent enough to cause needle vibration and so rapid that no distinction could be made between the continued line current changes and the changes caused by making and breaking the cathodic protection test current.

The entire pipe line is coal tar coated with glass innerwrap and asbestos felt outerwrap. Insulating flanges are installed on both sides of all pump stations and intermediate scraper traps. The effects of stray currents have been noted all along the 718-mile pipe line between Edmonton, Alberta and Vancouver, British Columbia and were found to be more severe in the remote mountain regions. Throughout the mountain areas soil resistivity is generally very high. Resistivities have been measured exceeding 10 million ohms per cubic centimeter and over distances of a mile or more soil resistivities exceed one million and 100,000 ohms per cubic centimeter at many points. However, resistivities below 1000 and as low as 150 ohms per cubic centimeter have been measured.

The stray currents were always present during a 10-week period of continuous surveying over a 380-mile section which was completely tested. No welding machines were operating on the line during the test period. There are no electric railways, electric operated mines or other similar sources of stray current within what would be considered interfering range of the pipe line. The general character of the fluctuations was more erratic than those originating from any previously encountered stray current source. Until a means is found to eliminate or at least limit these current fluctuations, future surveys will be arduous and it will be difficult to determine if a cathodic protection system is fully effective.

Currents of similar nature but of considerable less severity and magnitude (up to 5 amperes) have been measured on other Canadian pipe lines^{1,2} and on pipe lines in Texas, Oklahoma, and Missouri.³ It was found in these instances that insulating flanges and

Abstract

Line currents of unknown origin fluctuating as much as 20 amperes in upstream and downstream directions necessitated averaging from 20 to 30 measurements to get one of desired accuracy during coating conductance surveys on Trans-Mountain Oil Pipe Line Company's pipe line. The author postulates these currents may be of the same nature as those observed on other Canadian pipe lines and on lines in Texas, Oklahoma and Missouri, as well as on power systems in Canada and the United States. They are popularly attributed to sun spots, but may be due also to large adjacent bodies of ore. The currents make it extremely difficult for engineers to make reliable electrolysis surveys or tests of cathodic protection systems.

cathodic protection would effectively arrest the discharge of such currents. On the line being discussed, however, the maximum cathodic protection load permissible still allowed pipe-to-soil potential to "swing positive" up to 0.25 volts to a copper-copper sulfate half cell at certain locations.

Similar phenomena also have been encountered by electric power system operators throughout the United States and Canada. Attention was first directed to this subject in power systems when the operation of transformer banks and communication services were simultaneously affected at widely separated points. Investigation disclosed that peculiar direct currents were continuously flowing through the transmission network between remote system groundings. Currents with magnitudes of 80 amperes or more have been registered in Ontario transmission lines and such fluctuations have been abrupt and violent over periods of several hours. These disturbances were proved to be due to high intensity magnetic storms which are popularly attributed to "sun spots." The nature of the stray currents is similar to the effects encountered on the trunk line being discussed except that comparatively quiet periods are of relatively short duration and the stray currents preclude accuracy of any measurements and pose a novel electrolysis problem.

It is suggested that these currents may possibly have their origin in the solar activity responsible for magnetic and auroral disturbances. Some thought is being given to the possibility that the large quantities of mineral ores known to be present in the general area are causing this phenomena due to earth movements. These explanations are only conjectures, however. Any ideas and accounts of similar experiences from others engaged in the corrosion field will be welcomed and investigated.

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*Trans-Mountain Oil Pipe Line Co., Vancouver, B. C.

**Shell Pipe Line Corp., Houston, Texas.

Internal Corrosion in Domestic Fuel Oil Tanks*

By R. WIELAND and R. S. TRESEDER*

INTERNAL CORROSION of the small tanks in which heating oil is stored in homes has been a minor problem for a number of years. These tanks are made of relatively thin steel and a moderate amount of corrosion can result in perforation. In most instances the tanks have lasted 10 or 15 years. When perforation occurred, the condition of the tank usually was such that complete replacement was required. Since World War II the problem has become more serious. This was due, in part, to the greatly increased number of oil burner installations and, in part, to the increase in failure frequency experienced in several areas.¹ Although the number of failures was small relative to the large number of installations, it was sufficient to be of concern to retail fuel oil suppliers, tank manufacturers and oil companies. This paper presents results of an investigation which led to an understanding of the principal factors involved in this type of corrosion and to an inhibition treatment that has proved effective in large scale use.

Field Investigation

The tanks are fabricated from 12 to 14 gauge sheet steel, have welded seams and have capacities of *ca* 275 gallons. Generally, no protective coatings are applied to the internal surface of the tanks and there is no treatment (sandblasting, pickling) of the steel before or after fabrication. Tanks are not usually subject to significant external corrosion as they are installed generally in sheltered locations above ground, although in some installations tanks are buried.

At the start of this investigation inspections were made of a number of fuel oil tank installations where corrosion had become a problem. A few tank failures were found to have occurred in as short a time as one year, corresponding to a penetration rate of 80 mils per year. A significant number of failures occurred in tanks less than five years old.

All tank failures investigated occurred at the bottom of the tank within an area about one foot wide and extending the length of the tank. This area corresponds to the location of a bottom water layer. Examination of samples of steel cut from the bottoms of failed tanks revealed that corrosion took the form of localized pitting, with only moderate general corrosion (see Figure 1). Metallurgical examination of these sections showed no local variations in microstructure at the pitted areas. Microstructure of the steel used for the tanks was consistent with normal metallurgical practice. Subsequent laboratory tests

Abstract

Failure of domestic fuel oil tanks by perforation at the bottom as a result of internal corrosion has been a troublesome problem of the oil industry. Field investigation indicated the primary cause of corrosion to be the presence of small amounts of water in the tanks but did not provide a satisfactory explanation for the rapid localized attack that would occur sporadically. Laboratory data are presented which show that very rapid penetration can result from localization of the rusting action of water if imperfect coatings are present on the surface of the steel. Examples of such imperfect coatings are mill scale with breaks in the scale, thin sludge deposits and dirt collected on the bottom of the tank. There was no indication that the fuel oil was contributing any corrosion accelerating acidic constituents.

Addition of an alkaline sodium nitrite mixture to the individual tanks has been proved to be an effective means of preventing these corrosion failures. Supporting laboratory data are presented.

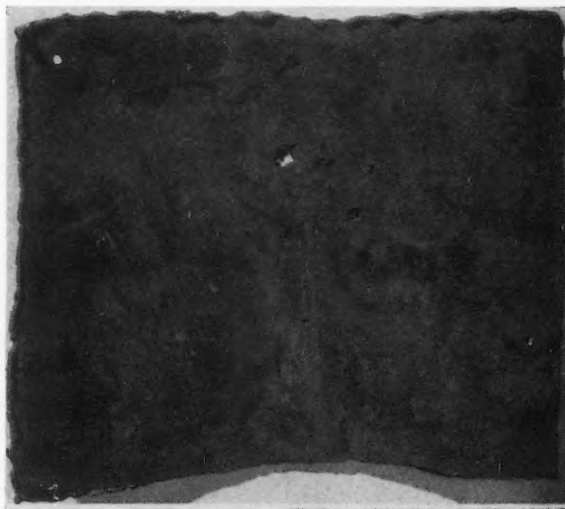


Figure 1—Corroded section from bottom of domestic fuel oil tank. Section shown is 22 inches wide.

TABLE 1—Analysis of Corrosion Product From Corroded Sections of Domestic Fuel Oil Tanks

Corrosion product scraped from bottom section of a typical corroded domestic fuel oil tank.

By Analysis	Percent W	Calculated Values	Percent W
Iron, Total.....	39.0	FeSO ₄	1.7
Ferrous Iron.....	7.5	FeCO ₃	1.9
Sulfur, Total.....	0.9	FeO · H ₂ O.....	10.6
Sulfide.....	<0.1	Fe ₂ O ₃ · H ₂ O.....	50.
Sulfate.....	1.1	NaCl.....	2.3
Chloride.....	1.4	CH ₂	30.3
Carbonate.....	1.0		
Carbon, Total.....	26.2	Total.....	96.8

*A paper presented at the Tenth Annual Conference and Exhibition, National Association of Corrosion Engineers, Kansas City, Mo., March 15-19, 1954.

* Shell Development Company, Emeryville, Cal.

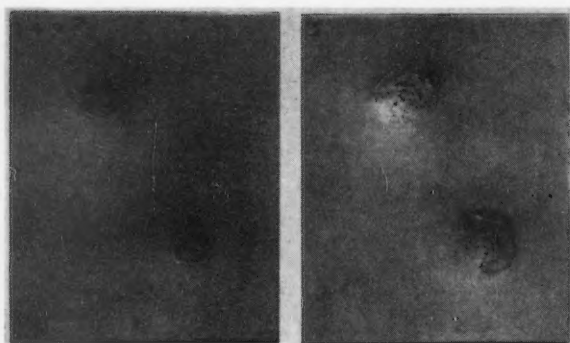


Figure 2—Typical attack occurring with fuel oil plus sea water in contact with clean steel. Test conditions as in Table 2.

TABLE 2—Corrosion of Steel by Various Hydrocarbons Plus Sea Water

Conditions: One 2.5 x 2.0 x 0.05-inch cold-rolled low-carbon steel sandblasted specimen with 2 small depressions (ca. $\frac{3}{4}$ -inch diameter, $\frac{1}{16}$ -inch deep) formed in the surface by cold pressing. Immersed in 100 ml hydrocarbon contained in a 3-inch crystallizing dish. After 4 hours ca. 0.2 ml synthetic sea water (SSW)^a added to each depression. Air atmosphere. Stagnant. Room temperature. Stored away from light. Duration, 52 weeks.

^a Made up using formula of Navy Specification 47S20.		Stock Solution	
NaCl.....	23. g.	KCl.....	10. g.
Na ₂ SO ₄ · 10 H ₂ O.....	8. g.	KBr.....	45. g.
Stock Solution.....	20. ml	MgCl ₂ · 6 H ₂ O.....	550. g.
		CaCl ₂ · 6 H ₂ O.....	110. g.
Dilute to 1 liter with tap water.		Dilute to 1 liter with distilled water.	

HYDROCARBON	Maximum Pit Depth, Mils	Gum Observed at End of Test
Cetane.....	15	Light yellow gum
n-Heptane.....	1	None
Kerosene.....	1	None
Light white oil.....	1	None
No. 2 fuel oil.....	13	Light brown gum

showed that there were no great differences in corrosion resistance among several samples of tank steel; similar results were obtained with a laboratory stock of cold-rolled low-carbon steel. It seemed unlikely that the type of steel used was a significant factor.

Analysis was made of several samples of solid material removed from corroded areas of tank bottoms such as that shown in Figure 1. The various samples were found to be similar in composition and to consist mainly of organic materials and iron oxide. A typical analysis is given in Table 1. No appreciable amounts of sulfur compounds were found. It was concluded that the corrosion product was primarily iron rust and the main corrosion reaction was that of the ordinary rusting of steel.

Analysis of oil samples from failed tanks yielded no significant information. Sulfur content was low, acidity ranged from 1 to 10 milli-equivalents per liter and peroxide content varied from 0.6 to 11 milli-equivalents per liter. There was no apparent correlation between refinery source of fuel oil and occurrence of tank failures.

To determine the extent and severity of water contamination, bottom fluid samples were taken from a number of customer's tanks in one city on the Atlantic Coast. In all cases the amount of water found was very small. The largest water sample obtained was less than $\frac{1}{2}$ pint. In many cases no measurable amount of water was recovered. Analysis of water

samples from several cities gave pH values from 5 to 8 and chloride contents ranging from 0.08 to 0.8 percent. High chloride values reflect contamination by sea water.

Traces of oxygen-containing water would be present normally in the tanks due to condensation from the air and oil owing to temperature changes. In addition, a slight amount of entrained water contamination could be expected owing to multiple transfers of the oil. At installations near the coast where deliveries are made by tankers, some sea water contamination might occur occasionally.

The conclusion from the field investigation was that corrosion was caused by traces of water in the fuel oil tanks. There was no indication that the fuel oil was contributing any corrosion accelerating acidic constituents. However, there was no immediate satisfactory explanation for the severe localized corrosion that would occur occasionally. The laboratory investigation, described below, provided an explanation for this effect and also established the suitability of an inhibitor treatment involving use of sodium nitrite.

Laboratory Test Procedure

The following simple laboratory test simulating tank bottom conditions was devised to determine the influence of a number of variables on corrosion and to evaluate preventive methods.

The specimen consisted of a 2.0 x 2.5 x 0.06-inch plate of cold-rolled low-carbon steel (0.06 C, 0.28 Mn, 0.05 S, 0.015 P, 0.01 Si) with one or two small depressions (ca. $\frac{3}{4}$ -inch diameter and ca. $\frac{1}{16}$ -inch deep) formed in the surface by cold pressing. These depressions served to hold water drops in place. The specimen was immersed horizontally in 100 ml of No. 2 fuel oil contained in a 3-inch crystallizing dish. After several hours drops of water were placed on the surface. Synthetic sea water was used in most cases in order to give a severe test condition. The test containers were stored at room temperature (ca. 70 degrees F) in the dark. The duration of the test varied from one week to one year. At the end of the test the specimens were removed and inspected for rust and sludge formation. The corrosion product was removed and the corrosion rate determined from pit depth measurements. Since the pitting observed often was quite erratic, tests with several specimens were required.

Effects of Fuel Oil Properties

In a simple test simulating the most obvious corrosion factors involved, i.e., a test in which clean steel was immersed in fuel oil and drops of sea water placed on the surface, only moderate attack occurred under the water drop in one week tests. In similar tests conducted for increasingly longer periods of time, pitting was observed frequently. In some cases, the pitting was severe (a pit depth of 14 mils was obtained in a 6 week test), but test results were erratic, with wide variations in pitting rate being observed. Typical examples of the pitting obtained in such tests are shown in Figure 2.

An attempt was made to correlate corrosion obtained in laboratory tests of various fuel oil samples

**TABLE 3—Effect of Breaks in Surface Coatings
On Corrosion of Steel in Sea Water**

Conditions: One 2.5 x 2.0 x 0.05-inch flat sandblasted low-carbon steel specimen. One 0.03 x 0.25-inch hole abraded through applied coating to bare metal surface at center of specimen, or in center of depression. Specimen placed in horizontal position on bottom of a 3-inch crystallizing dish. Stagnant. Room temperature. Stored away from light. Duration, as listed.

Application of Coatings:

Mill Scale: Specimen heated 6 hours at 1000 degrees F.

Petrolatum: Thin layer wiped on.

Wax: Microcrystalline wax (melting point 150 degrees F); thin coat brushed on hot specimen.

Sludge: Specimen immersed in fuel oil and stored for 1 year exposed to light. A sludge layer about 0.01-inch thick deposited on the surface.

Lacquer: Single coat of lacquer, cutback 50 percent with acetone, brushed on specimen.

Paint: White paint diluted 80 percent with linseed oil; thin layer wiped on.

Test A: One 3/4-inch diameter shallow (ca. 1/8-inch) depression formed in center of specimen by cold pressing before applying coating. Specimen immersed in 100 ml fuel oil. After 4 hours 1.5 ml synthetic sea water placed over hole in one large drop.

Test B: Edges and back of specimen coated with wax and covered with Bitu-plastic No. 22 (water-base coal tar paint) after coating applied. Specimens immersed in 100 ml synthetic sea water.

COATING	MAXIMUM PIT DEPTH, MILS		
	Test A Fuel Oil Plus SSW 2 Weeks	TEST B SSW Alone	
		2 Weeks	70 Weeks
None.....	< 1/2	< 1/2	< 1
Petrolatum.....	1	1	5 ^a
Wax.....	6	6	10 ^{ac}
Sludge deposited from fuel oil.....	3	3	.....
Lacquer.....	5	.....	.....
Paint.....	6	6	18 ^a
Mill scale.....	4	1	2 ^b
Mill scale plus petrolatum.....	4	4	23 ^a
Mill scale plus wax.....	6	6	> 50 ^{ac} Perforated

^a Coating had deteriorated badly at end of test.

^b Mill scale completely gone at end of test.

^c Specimens shown in Figure 4.

with analytical properties (peroxide content, acidity and gum content) or with source of fuel oil. No significant correlation was obtained. Addition of either organic peroxide or organic acidity to fuel oil samples resulted in no increase in corrosion.

To determine if the pitting noted above was characteristic of hydrocarbon liquids, or was peculiar to distillate fuel oil, a series of tests of varying duration was made with a variety of hydrocarbons. These included n-heptane, kerosene, cetane and white oil in addition to No. 2 fuel oil. Results of tests of one year duration are given in Table 2; data from tests of shorter duration were similar qualitatively to these. Pitting was observed with cetane and fuel oil, but not with n-heptane, kerosene or white oil. It was considered significant that appreciable sludge deposits were noted on the steel surface only in those tests in which pitting occurred. In view of the tests with various coatings to be described below, it seems reasonable to conclude that severe pitting observed with fuel oil plus water in contact with clean steel is promoted by sludge deposition from the fuel oil.

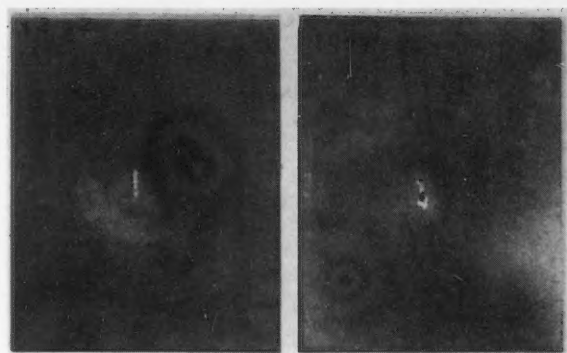


Figure 3—Typical attack occurring with mill scale coated specimens exposed to fuel oil plus sea water. Test conditions as in Table 3 (Test A). 1/32 x 1/4-inch bare spot abraded in mill scale in center of coating at start of test.

Wax Coating

Mill Scale
plus
Wax Coating

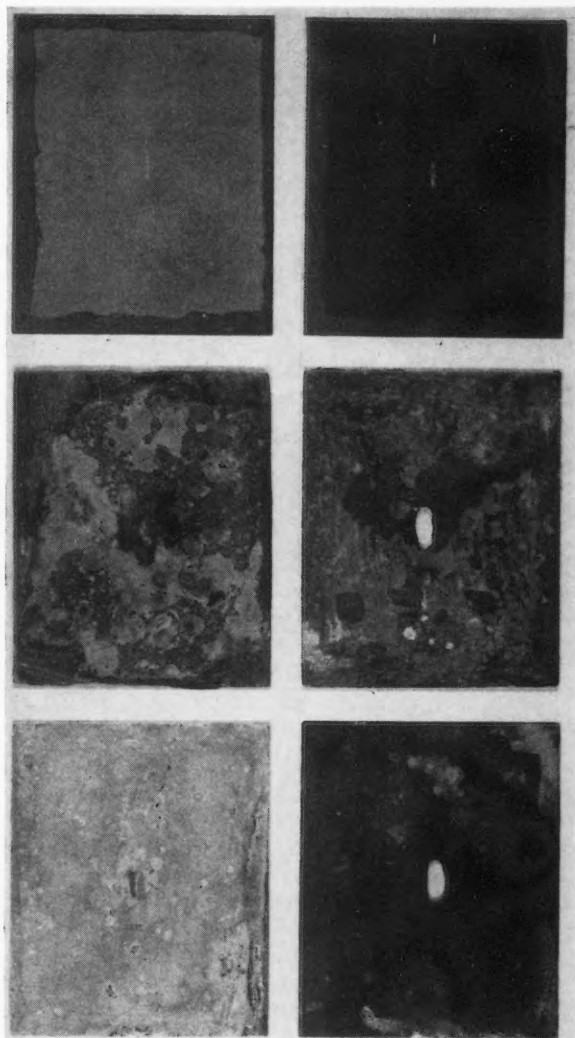


Figure 4—Effect of holes in permeable coatings on corrosion of steel in sea water. Test conditions as in Table 3 (Test B). Duration, 70 weeks. Back and edges of specimens coated with wax plus water-base coal tar paint.

Influence of Imperfect Coatings

That severe localized attack of steel can occur at breaks in a mill scale coating is well known. This is attributed to the fact that mill scale is an electrical conductor and is cathodic to steel; thus the exposed metal becomes anodic and, owing to the large cathodic area, suffers pronounced localized corrosion. This effect was duplicated in the laboratory by exposing mill scale coated steel specimens to sea water and fuel oil. The mill scale coated specimen was prepared by heating the specimen for six hours at 1000 degrees F. A small bare spot was abraded in the coating prior to test. In a one-week test, pits up to 17 mils deep were measured (corresponding to a corrosion rate of 880 mils per year) compared to the non-localized etching type of attack (<25 mils per year) that took place when no mill scale was present. In some cases the entire bare spot was corroded severely; in others scattered pitting was observed within this area. Typical specimens from such tests are shown in Figure 3.

Additional tests were made to determine if similar effects could be obtained with other types of coatings. It was found that this effect could occur with almost any semi-permeable coating providing a small area of steel was exposed. Coatings which showed this effect included paraffin wax, petrolatum, lacquer, paint, and sludge deposited from fuel oil (see Table 3). In some of these tests (e.g., with petrolatum and wax coatings) it was necessary to use specimens immersed in sea water with no fuel oil present in order to avoid solution of the coating. In 2-week tests, localized pits as deep as 11 mils (corrosion rate of 290 mils per year) were obtained with imperfectly coated specimens. In a 70-week test, one specimen was perforated, corresponding to a corrosion rate of greater than 50 mils per year (see Figure 4). In these two cases, the coating used was wax on mill scale. It would be reasonable to expect that a coating of

sludge deposited from fuel oil could give equivalent results. The sustained corrosion rates obtained in these various tests are of the same magnitude as those observed in actual tank installations. The less severe pitting observed in prolonged tests with coatings other than wax over mill scale was attributed in part to the gradual breakdown of the coating which provided a larger anodic area, thus decreasing the intensity of attack at the initial bare spot.

The essential requirement for this localized corrosion appears to be that the coating be permeable to oxygen and water so that the underlying metal can become cathodic to the exposed area. This mechanism was supported by the observation that water under blisters formed in the coatings was strongly alkaline. Further tests showed that increasing the thickness of a coating, and thus decreasing its permeability to water and oxygen, reduced the intensity of the pitting markedly. Pitting in a large bare spot was less severe than in a small one. The intensity of pitting was reduced when several bare spots occurred in the same area. This mechanism is in agreement with that proposed recently by C. G. Munger¹ to explain the effect of corrosion on the breakdown of protective coatings for steel.

Confirmation of this mechanism was obtained in a simple beaker test in which measurements were made of the potentials developed in sea water, between clean steel coupled to steel coated with wax or mill scale; area ratio 1 to 10, respectively (Figure 5). After 20 minutes the mill scaled steel was 185 millivolts cathodic with respect to the bare steel electrode. When the test was terminated after 15 days, the potential had decreased to 85 millivolts. This reduction is attributed to gradual breakdown of the mill scale coating. After one day the potential of the wax coated steel rose to about 125 millivolts (also cathodic with respect to the bare electrode) and remained at that level for 15 days when the experiment was terminated. Here the delay in attainment of a high cathodic potential is attributed to the time required for permeation of the wax coating by air and water.

Solid particles such as sand, clay, and petroleum coke, when present on the surface of the specimen exposed to fuel oil and sea water, also increased localized attack (Table 4). A differential aeration mechanism was probably involved here also.

Influence of Water Composition

Comparative tests (Table 5) were made with various water samples including samples from customers' tanks and synthetic samples of varying chloride ion content obtained by diluting synthetic sea water. Severe localized attack was obtained with mill scaled specimens exposed to the field samples and to those synthetic samples which contained as little as 0.0008 percent chloride ion. It would appear that any water having appreciable conductivity could give rise to pronounced localized attack.

Influence of Fuel Oil Additives

In recent years, surface active compounds have been added to No. 2 fuel oil to reduce formation

TABLE 4—Effect of Solid Particles
On Corrosion of Steel in Fuel Oil Plus Sea Water

Conditions: Test procedure as described in Table 2. Duration, as listed. Approximately 25 mg solid material added to each depression when sea water was added.

SOLID MATERIAL ADDED	MAXIMUM PIT DEPTH, MILS	
	2 Weeks	52 Weeks
None.....	1½	8
Sand.....	6	18
Petroleum coke.....	1	19
Soil.....	1	..
Clay.....	2	..

TABLE 5—Effect of Water Composition
On Corrosion of Steel in Fuel Oil

Conditions: Mill scale test procedure described in Table 3 (Test A). Duration 1 week.

WATER	Maximum Pit Depth, mils*
100 percent distilled water (DW).....	0.0
99.96 percent DW plus .04 percent SSW (0.0008 percent Cl ⁻).....	3.1
99.6 percent DW plus 0.4 percent SSW (0.008 percent Cl ⁻).....	9.3
95.7 percent DW plus 4.3 percent SSW (0.08 percent Cl ⁻).....	14.8, 5
100 percent synthetic sea water (SSW) (1.85 percent Cl ⁻).....	17.6, 4
Water from customer tank (0.08 percent Cl ⁻).....	3
Water from customer tank (0.8 percent Cl ⁻).....	10

*Each value given represents an individual test.

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during storage of solid particles which would cause plugging difficulties in oil burner jets and screens. Corrosion tests of the various types mentioned above were made with and without such additives present. No direct effect on localized corrosion was observed. It is conceivable, however, that such additives could have an indirect effect in two ways. In one, the polar additive might tend to increase the quantity and stability of emulsions of small amounts of water in oil, the water subsequently separating out in the consumer's tank. The additive might also affect the type and quantity of sludge deposited in the tank, e.g., detergent action of the additive might prevent deposition of a thick protective layer of sludge on the bottom of the tank.

Influence of Age of Tank

The various laboratory results described above provide an explanation for the phenomenon observed in some areas that newer tanks apparently were suffering a higher frequency of leaks than older tanks. During the early life of a tank, conditions for rapid local attack may exist owing to the presence of a fairly intact mill scale coating plus an irregular thin deposit of sludge; subsequently, conditions for local attack become less favorable as the mill scale is attacked and the sludge coating increases in thickness.

Preventive Methods

Since the essential corrosion reaction is that of the rusting of steel in substantially neutral water, consideration was given to preventive methods normally employed in such situations. Protective coatings appeared to be impractical for protecting old tanks in use and would be rather costly for new tanks. Removal of water from the tanks as a preventive measure, e.g., by installing a bottom drain valve, seemed hopeless since only traces of water were required to cause corrosion and no practical water removal method would be expected to be completely effective. Attention was centered on inhibition as the most practicable preventive measure. Use of oil-soluble inhibitors did not appear promising in view of the low concentration that could be added economically to such a low priced product as fuel oil and of the difficulty of achieving inhibition by such means under stagnant conditions. Laboratory tests with a few of the more effective oil-soluble rust preventive additives confirmed this view. The obvious answer then was to use a water-soluble inhibitor which could be added in a simple manner to each installation.

Comparisons of the effectiveness of various common water-soluble inhibitors were made in tests described in Figure 6. For convenience, and because it represented a severe test condition, these comparisons were made using mill scale coated specimens exposed for one week to fuel oil plus sea water, the sea water containing varying concentrations of the inhibitors being evaluated. The criterion for passing in this test was the complete absence of rust at the end of the test. The most effective inhibitor tested was alkaline sodium nitrite, which gave complete protection from both general and local attack at a concentration of 0.25 percent. Sodium nitrite alone required a concen-

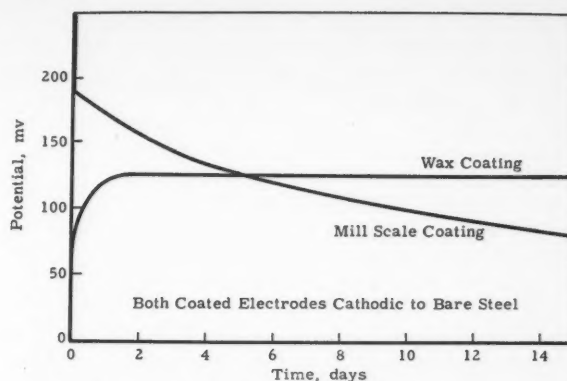
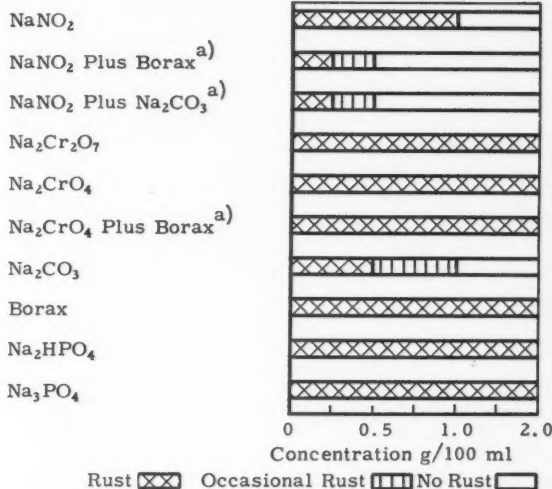


Figure 5—Potential of coated steel vs bare steel in sea water. Test conditions: One 0.05 x 2.0 x 2.5-inch sandblasted low-carbon steel specimen completely coated with wax or mill scale (Table 3) coupled to one 0.05 x 0.25 x 2.0-inch ground specimen of the same steel. Both immersed in synthetic sea water. Open circuit potential reading taken daily by potentiometer.



a) Ratio 3:1 Listed according to NaNO₂ or Na₂CrO₄ concentration

Figure 6—Effect of water soluble inhibitors on the corrosion of steel by fuel oil plus sea water.

tration of 1.0 percent. The effectiveness of alkaline sodium nitrite was confirmed in this and other types of laboratory tests, e.g., the test with clean steel plus a sand deposit, for test durations as long as one year. In the one week mill scale test, sodium dichromate was ineffective at the concentrations tested. Sodium chromate and alkaline sodium chromate were much less effective than sodium nitrite, requiring a concentration of 5 percent to give complete protection. Alkaline compounds alone such as sodium carbonate, disodium phosphate, trisodium phosphate, and borax were not as effective as the alkaline sodium nitrite in the one week tests. In addition, it is considered that their usefulness would be limited by the possibility of neutralization by carbon dioxide during long term storage.

In view of the excellent results it gave in the laboratory, alkaline sodium nitrite was subjected to ex-

tensive field testing. In one large marketing area the mixture of sodium nitrite and an alkaline buffer, both in powder form, was introduced into each individual tank as a four ounce dose, the powder being dumped into the fill line just prior to an oil delivery. The effect was dramatic. An 87 percent reduction in tank leakage was reported from that area in the following year. Apparently, the inhibitor was effective in stopping further corrosion in many tanks which were badly corroded at the time of treatment. Subsequent analyses of tank bottom samples have indicated that effective concentrations of inhibitor are maintained for several years following a single treatment. The sodium nitrite concentration in water, obtained from typical tanks one year after treatment was initiated, ranged from 3 to 36 percent and the pH from 7 to 9. At present over 50,000 tanks have been treated in this manner, and results have been highly successful.

Summary

Presence of traces of water was found to be the primary cause of corrosion experienced in domestic fuel oil tanks. An essential requirement for the severe attack observed was shown to be an imperfect coating on the surface of the steel so that small exposed areas of steel could become the anodes for an extensive cathode, with resultant pitting action. Breaks in the original mill scale coating, or an incomplete coating of sludge deposits from the fuel oil could act in this way. The presence of dirt on the bottom of the tank would also serve to increase pitting attack. Satisfactory inhibition of the attack was obtained by addition of an alkaline sodium nitrite mixture to individual tanks.

Acknowledgment

The authors acknowledge the cooperation of their colleagues in Shell Oil Company and Shell Development Company, especially the contributions of W. A. Sullivan and H. R. Heiple and the guidance of A. Wachter.

References

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2. C. G. Munger. Plastic Coatings and Corrosion. *CORROSION*, 4, 557 (1948).

DISCUSSION

Questions by F. L. LaQue, International Nickel Co., Inc., New York:

1. What is the probable mechanism by which the coating of wax aggravated the cathodic effect of mill scale? 2. Why not deal with the problem by removing the mill scale in the first place?

Replies by R. Wieland:

1. In most of the tests lasting longer than a few weeks the mill scale coating was attacked resulting

in a larger anodic area so that the severity of corrosion at the hole was reduced. Wax acted as a semi-permeable protective coating for the mill scale limiting corrosion to the original area of the hole. This caused the severe pitting attack.

2. Though removal of the mill scale coating from the steel surfaces of the tank would prevent many of the failures in new tanks, this would not be a completely effective solution to the problem as it was found that pitting attack could occur in the absence of mill scale. For example, discontinuous sludge deposits on the tank bottoms could act as semi-permeable coatings and accelerate pitting corrosion.

Question by Kenneth R. Barker, Ashland Oil & Refining Co., Ashland, Ky.:

What concentrations of oil soluble and water soluble corrosion inhibitors were used?

Reply by R. Wieland:

Oil soluble inhibitors were tested at concentrations of 25 to 1000 ppm in the oil phase. Water soluble inhibitors were tested at 1000 to 50,000 ppm in the water phase.

Question by James T. Dwyer, Jr., Gulf Oil Corp., Port Arthur, Texas:

In speaking of fuel oil, do you mean residual fuel oil or distillate furnace oil?

Reply by R. Wieland:

The fuel oil referred to in this paper was distillate furnace oil.

Discussion by Frank N. Speller, Consultant, Pittsburgh, Pa.:

Last year a few cases of severe corrosion in domestic fuel oil tanks came to my attention. These tanks were .07 inch thick and were pitted through within two years along a strip about 5 inches wide inside on the bottom where water collected. The pitting occurred at breaks in the mill scale and was naturally rapid because of the high cathode/anode ratio of area. One of my family had a similar experience in another locality and lost 250 gallons of oil on the basement floor. The primary causes are evidently water and dissolved oxygen. In view of the great hazard some regulation and remedy is obviously needed. The choice would probably be governed by the cost, and might include: Thicker walls and removal of mill scale; suitable inhibitors; or suitable coatings on scale free surface. Fuel oil is said not to produce any corrosion problems, as a rule, in pipe lines or tankers where the oil is agitated. However, an oil soluble inhibitor may give the surest protection from the refinery all through the system.

Inhibitor Evaluation by the Pearson Null Bridge*

By BARTON L. CROSS and NORMAN HACKERMAN

Introduction

GOOD, RAPID METHODS for evaluating corrosion inhibitors are not yet available. In systems where the electrochemical mechanism of corrosion may be presumed to operate, it has been customary to measure the change in some electrical property of the system as a result of inhibitive addition. Commonly, change in corrosion potential has been the criterion. However, this quantity alone is insufficient.¹ Ideally, measurement of a change in local cell current or the full self-polarization diagram is needed. Methods for getting such quantities are difficult or are restricted to a few special systems.^{2,3,4}

Pearson⁵ considered that changes taking place at local electrodes of a corrosion couple were largely explainable in terms of resistance changes and devised a system for measuring such changes. His bridge is capable of obtaining anode and cathode polarization curves with applied current as well as "film resistances" at each electrode.

If the principal effect of inhibitors is to provide a barrier at the metal surface and if the barrier interferes with current flow, then the net result is introduction of an ohmic resistance.* The Pearson null bridge is suited to measuring such resistance changes as occur, particularly since it is capable of determining these values separately for anodes and cathodes.

Although the bridge was already being studied elsewhere for the purpose indicated above, it was decided to carry on this investigation because of the procedure's potential usefulness. Materials were chosen for which mechanisms postulated on the basis of other methods were acceptable to most workers in the field. Interpretation of results given by the bridge are compared directly to the generally accepted postulated mechanism.

Experimental

The Bridge

The original version⁵ as modified by Pearson⁶ was used essentially unchanged. Such modifications as were made were to increase stability of the circuit and convenience of handling.

Operation of the bridge may be better understood with the aid of Figure 1. The corrosion couple is shown as a metal partially coated with a porous scale. Potentials of the anode and cathode are given as E_a and E_c respectively, R_f is the film resistance, R_s is the resistance of solution in the film pores, I_a



BARTON L. CROSS—Mr. Cross has been with the Naval Ordnance Test Laboratory, Inyokern, Cal., since March, 1953, where he is occupied with research in physical chemistry and instrument design. A graduate of the University of Illinois and the University of Texas, he served in the U. S. Army Air Corps from 1942 to 1946.

NORMAN HACKERMAN—Chairman of the chemistry department and director of the corrosion research laboratory at University of Texas, Austin, Dr. Hackerman, besides many years of activity in NACE, is a member of other technical organizations and author of many publications on corrosion. A sought after speaker on corrosion subjects, he has been chairman of the NACE Education Committee for several years, a member of the association's board of directors and an officer of other technical organizations.



Abstract

A Pearson null bridge was built in order to determine its usefulness in the evaluation of corrosion inhibitors. Eight compounds and three commercial inhibitors were tested using steel in aqueous sodium sulfate solution as the corrosion system. The materials used had all been studied by various other means, thereby permitting comparison of previous results with those obtained by this method. As an estimate, this procedure gave about 70 percent correlation with other methods, as far as inhibiting mechanisms are concerned. This is on the basis of qualitative classification only. As a quantitative tool, the bridge in its present form appears to be considerably less useful.

is the anodic cell current and I_c is the cathodic cell current. The local action current is given by

$$I_l = \frac{E_c - E_a}{R_f + R_s} \quad (1)$$

and the measured corrosion potential, E , by

$$E = E_a + I_a R_s - (E_c + I_c R_s) \quad (2)$$

$$= \left[E_a + \left\{ I_l - I \left(\frac{R_f}{R_s + R_f} \right) \right\} R_s \right] -$$

$$\left[E_c - \left\{ I_l + I \left(\frac{R_s}{R_f + R_s} \right) \right\} R_f \right] \quad (3)$$

where

$$I_a = I_l - I \left(\frac{R_f}{R_s + R_f} \right) \quad (4)$$

and

$$I_c = I_l + I \left(\frac{R_s}{R_f + R_s} \right) \quad (5)$$

*A paper presented at a meeting of South Central Region, National Association of Corrosion Engineers, Tulsa, Okla., October 7-9, 1953.

*The authors do not necessarily subscribe to this as the only way of accounting for the observed effects. To it must be added the very good possibility of an actual deactivation of the surface atoms in the metal by adsorbed inhibitor. As a matter of fact, the non-linearity of experimental polarization diagrams is evidence that Ohm's law is not the only factor.

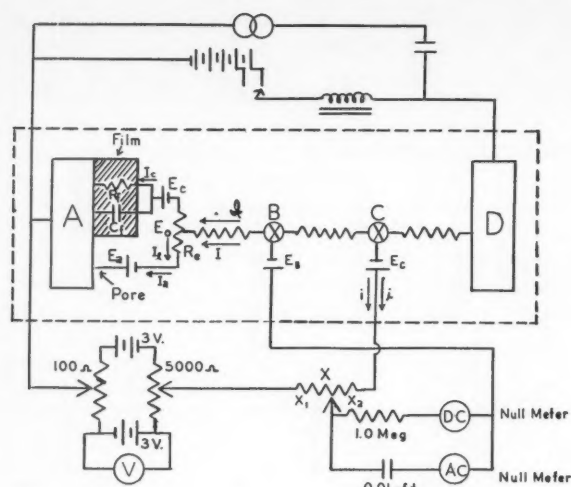


Figure 1—Sketch of the corroding metal and the bridge (based on Figure 2 of reference 5).

The whole cell may be sectionized by the boundaries: a) electrode-film, b) film-adjacent electrolyte, c) adjacent electrolyte-main electrolyte, d) main electrolyte-calomel half cell B, e) main electrolyte-calomel half cell C, f) main electrolyte-input electrode. Potentials and IR drops of each segment shown are measured separately by using AC and DC circuits with the bridge.

It is necessary to use special precautions in making potential measurements because two currents flow in the corrosion cell: the applied current between test and input electrodes, and the local action current. The latter is assumed to be normal to the surface, since resistance of the electrolyte is much greater than that of the metal. The calomel half cells must be located outside the path of the local action current.

Direct and alternating currents are applied between the test electrode and input electrode, with part of the current by-passed through the resistance bridge, X, from the calomel cell, C. Total potential between electrode A and half cell B is made up of IR drop through the electrolyte, IR drop of the surface film on A, potential of B, and polarized potential of A. The latter is that part of the measured potential which is not accounted for by half cell potentials and IR drops.

A null point is found first by applying 1000 cps AC between electrodes. With bridge X adjusted for the null point, IR drop of the electrolyte from A to B is equivalent to IR drop in portion x_1 of the bridge resistance. This setting automatically removes electrolyte resistance from the potential readings so that when DC is applied, the observed potential includes only film resistance and polarized potential (contribution by the calomel half cell remaining constant). Thus the measured potential becomes independent of the position of the half cell, provided it is outside the boundary b.

To obtain the film resistance at any polarization value the direct current is decreased by 10 percent.

A corresponding voltage change is indicated on the DC null meter. When bridge X is readjusted and the null meter value transferred to voltmeter E, the voltage remaining on E is the difference between the potential of half cell B and the polarized electrode potential corresponding to the applied DC current.

The following equations summarize this. In these, the symbols not yet identified have the following significance:

- E_o = polarized potential of test electrode;
- E_b and E_c = potentials of half cells B and C;
- I = applied DC;
- i = applied AC;
- i and i = DC and AC bridge operating currents respectively;
- R_s = solution resistance between A and B.

Using AC current, the potential observed on the AC null meter is:

$$N_{AC} = IR_s \quad (6)$$

When bridge X is adjusted for the AC null

$$ix_1 = IR_s \text{ and } ix_1 = IR_s \text{ since } \frac{i}{I} = \frac{i}{I} \quad (7)$$

This adjustment removes R_s from consideration in the circuit.

Adding DC current, the potential observed on the DC null meter is:

$$N_{DC} = E_o(I) + IR_f - E_B = V_{DC} \quad (8)$$

When this reading is transferred to the voltmeter E, and the applied DC current is decreased by 10 percent,

$$\Delta N_{DC} = \Delta E_o(I) + \Delta IR_f = \Delta V_{DC} \quad (9)$$

or

$$\Delta V/\Delta I = R_f + \Delta E_o/\Delta I \quad (10)$$

To obtain E_o , bridge X is readjusted to remove the resistive components and this negative value on the null meter is transferred to voltmeter E.

$$E = V - I \Delta V/\Delta I \quad (11)$$

$$E = E_o(I) - E_B - I \Delta E_o/\Delta I \quad (12)$$

The value of E_o depends on the resistance of the electrolyte in the pores of the electrode, the film resistance and the local cell potentials. Although the potentials of the local cells may be affected by the applied current, I , their potential change will be proportionately smaller than the change in I since their potentials are also determined by other factors which are not affected by current I .

Therefore, since ΔI is only a small fraction of the original current I , ΔE_o will be even smaller. For a reasonable approximation, it may be assumed that $\Delta E_o \approx 0$, and therefore, from equation (10),

$$R_f = \Delta V/\Delta I \quad (13)$$

A more complete analysis is given in the appendix of Pearson's original article.⁵

Current supply for the bridge includes both AC generators and regulators. A variable frequency audio oscillator and AC amplifier was used for the alternating current while the DC supply consisted of a 45-volt cell and 4.5 volts in dry cells which could be switched into the circuit in series. Appropriate potentiometers and switches along with a microammeter gave the necessary control. Blocking chokes and condensers were included in AC and DC circuits respectively to separate them from one another.

An adjustable one megohm potentiometer served as the bridge X. The DC potentials were observed via a DC amplifier and vacuum tube voltmeter. However, the shunting effect of the bridge does not permit obtaining accurate values directly from the voltmeter, so an auxiliary backing-out circuit and millivoltmeter were used. A separate AC amplifier and vacuum tube voltmeter were used to read AC potentials.

The Cell

An SAE 1020 sheet steel piece served as the test electrode. It was immersed in a beaker containing 250 ml. of 5 percent Na_2SO_4 in water. This beaker was connected electrolytically to a second one by a U-tube filled with the same solution. The platinum input electrode was situated in the second beaker. Saturated calomel electrode B was in the first beaker and C was in the second. Provision was made for stirring and for bubbling nitrogen through the solution. All runs were made at $30 \text{ degrees} \pm 2 \text{ degrees C}$.

The bridge was too unstable to permit using one blank run for all comparisons. Therefore, each inhibited run was compared with a blank run made immediately before it with the identical system.

Materials

Distilled water was used throughout. CP Na_2SO_4 , ZnSO_4 and K_2CrO_4 were used. Research grade di-n-butylamine, di-isobutylamine, isobutylamine and isopropylamine were obtained from Research Laboratories Division of Eastman Kodak Co. Crystalline ethylene thiourea was purchased from Sharples Chemical Company. Practical grade thiourea was ordered from Eastman Kodak Co. Organic Chemicals Division. The commercial inhibitors were all nitrogen-containing, high molecular weight compounds. They included: A—a water soluble ternary amine chloride; B—an oil soluble nitrogen ring compound; C—a water soluble compound of similar structure.

The steel was coated with a water resistant lacquer so as to leave an area of 7.8 cm^2 open on one face. This section was abraded with 2/0 emery and then washed carefully to remove all grit.

Procedure

A brief summary of the procedure for operation of the bridge is appropriate here, but only continued use of the instrument permits one to become proficient in its operation.

A null point is first obtained with AC, then the desired DC is applied. The DC amplifier is set on

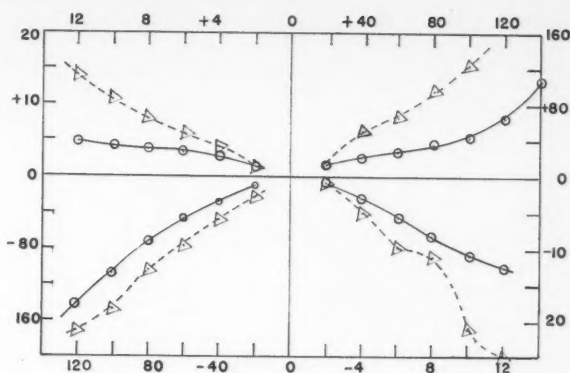


Figure 2—Polarization and film resistance curves with isopropylamine.

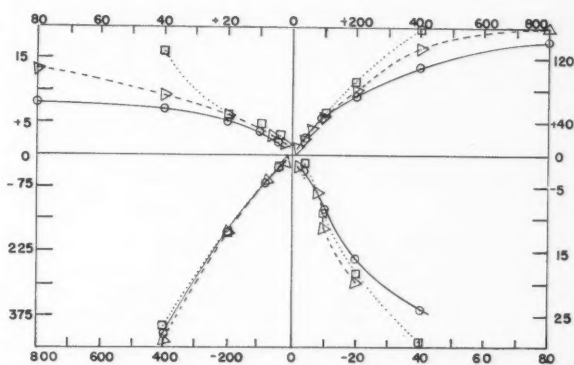


Figure 3—Polarization and film resistance curves with isobutylamine: Δ —2 percent by weight; \square —6 percent by weight.

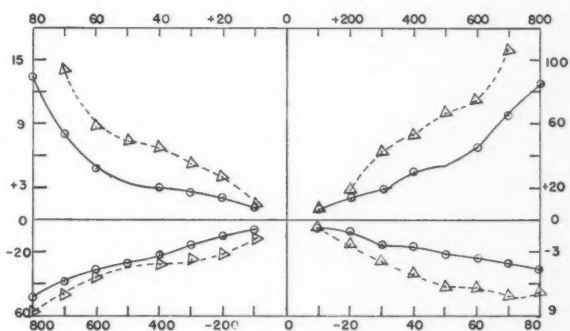


Figure 4—Polarization and film resistance curves with di-n-butylamine.

the desired sensitivity, as noted on a milliammeter and maintained at this sensitivity throughout the run. Application of DC produces a deflection of the DC null meter which becomes steady after several seconds. Backing-out voltage is then adjusted until the null indicator is back to its original position. Polarized potential is read off the millivoltmeter in series with the backing-out circuit. DC input is then increased by 10 percent. After correcting for increased current, ΔE is read from the DC null meter. The latter is calibrated against the millivoltmeter and used in this way because deflection is too small to read on the millivoltmeter directly. Both anodic and cathodic runs are made the same way.

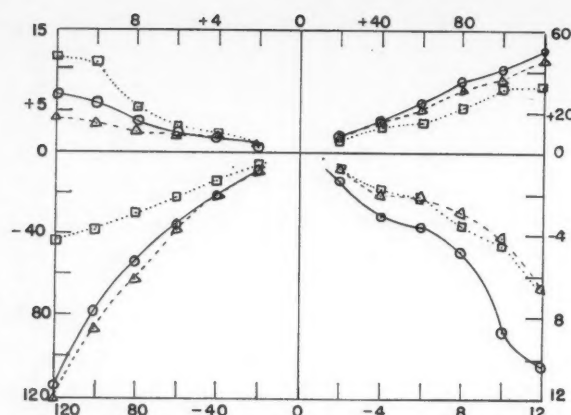


Figure 5—Polarization and film resistance curves with Inhibitor A: Δ —2 percent by weight; \square —6 percent by weight.

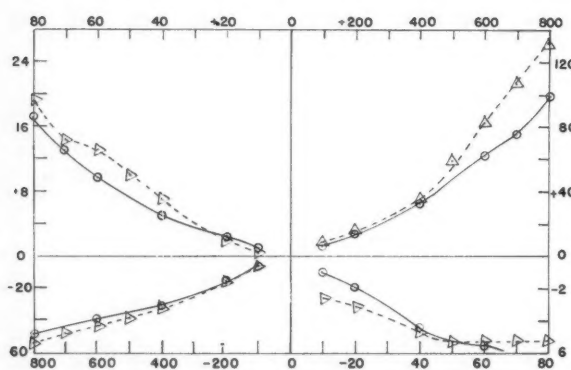


Figure 6—Polarization and film resistance curves with Inhibitor C.

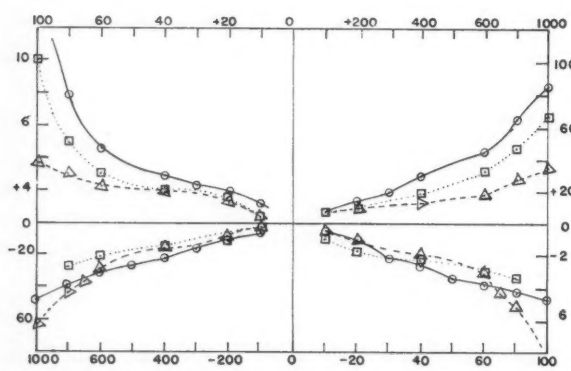


Figure 7—Polarization and film resistance curves with thiourea: Δ —0.4 percent by weight; \square —4 percent by weight.

In the present study inhibitor was then added and the runs repeated. Four runs were made for each inhibitor, an anodic and a cathodic blank plus an anodic and a cathodic run with inhibitor in the system.

Between 100 and 200 μa the potential became steady quickly, but at higher currents it took longer to reach this state. This is contrary to results customarily obtained in the more usual polarization experiments. In some runs the potential reached a rather high peak and then decreased substantially to the constant value.

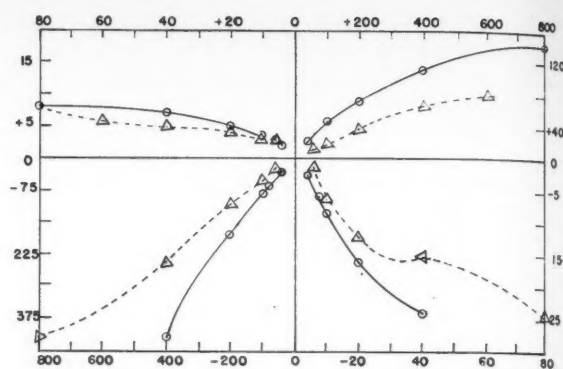


Figure 8—Polarization and film resistance curves with ethylene thiourea.

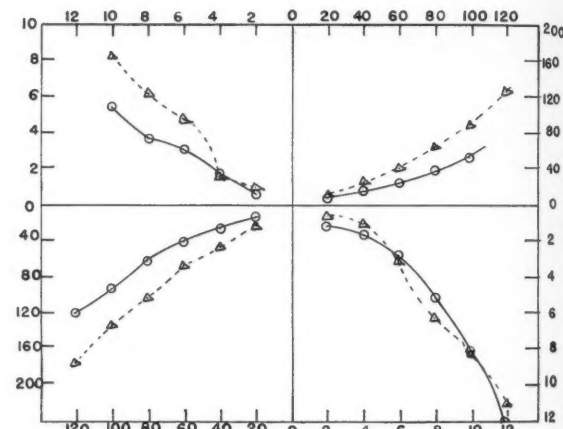


Figure 9—Polarization and film resistance curves with K_2CrO_4 .

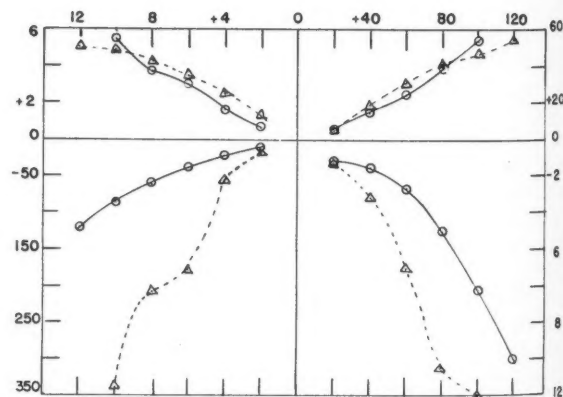


Figure 10—Polarization and film resistance curves with ZnSO_4 .

Results

Typical data are plotted in Figures 2 through 10. Blank runs are drawn as solid lines and results with inhibited systems as broken lines. The upper right quadrant shows anodic polarization curves and the lower left quadrant, cathodic polarization curves. Anodic "film resistance" (ΔE vs ΔI) curves are in the upper left quadrant and analogous cathodic curves

in the lower right. The ordinates are given in millivolts and the abscissas in microamperes.

In all cases the only effect to be considered is that of the additive on the slopes of these curves. Since there is considerable variation in slope on any one curve, only the "average" effect is used.

Amines

These have been said by Mann,⁷ among others, to be effective because they adsorb at cathodic areas and interfere with processes there. However, this postulate has been disputed by some^{8, 9} who maintain that it is inherently inconsistent. Figures 2 through 4 (the di-isobutylamine results are not markedly different and are not given) show that the slopes of both anodic and cathodic polarization curves are influenced by the additives, the former to a larger extent. Furthermore, these results do not give any clear cut relationship to molecular geometry as has been proposed.⁷ A suggested determining factor is solubility of the inhibitor⁹ and it is noteworthy that disubstituted amines are less soluble than mono-substituted amines. However, this alone is insufficient to explain observed effects in this and other studies. Additional factors such as effect of the organic radical on electronegativity of the functional group are considered elsewhere.⁹

In general, higher inhibitor concentrations showed increasing polarizing effects as might normally be expected. This is not always the case, since at higher concentrations some inhibiting materials become activators, probably by depolarizing action.¹⁰

Commercial Corrosion Inhibitors

The ternary amine A is said to be a cathodic inhibitor also. In this case, at 2 percent by weight there was little cathodic effect, while some anodic polarization did occur (Figure 5). With 6 percent by weight, significant cathodic polarization was found, as shown also by the ΔE vs ΔI curves. It is quite likely that the material acted as a detergent, in essence decontaminating the anodes. A considerable amount of froth formed during these experiments and is cited in support of this view. Because of this likely possibility, it is even more certain that the bridge viewed this material as a cathodic inhibitor.

Inhibitor B produced no effect on any of the four curves, quite likely because of its insolubility, since it shows good inhibitive properties according to other methods, *e.g.*, when used in an oil phase. This points up the fact that these materials do not just form an oil film since they could do so from suspension to some extent, even if not as well as from solution.

The water soluble inhibitor C gave an anodic effect only according to Figure 6. This is what would be predicted on the basis of views held at this laboratory. However, though the effect was reasonable to the present workers, quantitatively it was much too small.

Thiourea and Ethylene Thiourea

The results with these materials are shown in

Figures 7 and 8 respectively. Cavallaro and Bolognesi¹¹ found that this general class of compound acted anodically and cathodically. In this laboratory a large number of these compounds have been studied over an extended concentration range and some were found to be effective activators under certain conditions. Both this effect and the inhibitory action shown were related to chemical structure.¹⁰

Thiourea showed anodic depolarization decreasing at higher concentration and no cathodic effect at all. Ethylene thiourea showed depolarization on both limbs of the curve. The anodic depolarization might be explained by formation of a complex with iron which causes the metal potential to become more negative. Complex formation with an iron ion on the surface and still in the lattice may account for even greater changes toward more negative values. The cathodic depolarization comes about by electrochemical reduction of the ethylene thiourea, a postulate supported by the fact that hydrogen sulfide was produced.

Results with the bridge for these two compounds, however, are not readily interpretable, and do not seem to fit too well some of the present concepts of their influence.

Potassium Chromate

Hoar and Evans¹² attribute the inhibitive effect of this compound to formation of a self-repairing mixed oxide film. Others^{13, 14} suggest adsorption of the anion as the important initial factor. In either event it is believed to polarize anodes, although some cathodic effect is also postulated on the basis of the adsorption theory. Cathodic depolarization by chromate¹ has also been reported.

Polarization is observed on both anodic and cathodic curves in Figure 9. A sharp increase in polarization seems to be developing at about 120 μ on the anodic curve. The cathodic curve shows a more constant increase in polarization with current increase. The ΔE vs ΔI plots show little effect on the cathodic side, but an increase on the anodic side. Thus, this material checks satisfactorily except for extent of the effect.

Zinc Sulfate

This compound was chosen as a good example of a purely cathodic inhibitor. Figure 10 shows a cathodic effect very strikingly, with no effect anodically. This cathodic effect was the largest observed throughout the work. There is some thought that the material functions cathodically by precipitating as the hydroxide at the cathode. In this work a whitish material was found on the electrode after cathodic polarization at higher current densities.

The Film Resistance Curves

The ΔE vs ΔI curves followed the E vs I curves by and large. If the curves were useful quantitatively it would have been possible to calculate the contribution of film resistance to the polarized potential.

However, there is nothing available here that permits drawing any conclusions of this nature.

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NACE TECHNICAL COMMITTEE REPORTS

Publication 54-5

A Report of Technical Unit Committee T-1G on Sulfide Stress Corrosion Cracking*

Sulfide Corrosion Cracking Of Oil Production Equipment

A FEW years ago the oil industry encountered a new materials problem, that of rapid failure, by cracking, of high strength steel tubular goods and wellhead equipment in deep high pressure sour gas and oil wells. Although the number of fields involved initially was small, the importance of the problem was recognized quickly by the operating companies directly concerned. A single tubing or casing failure could lead to a costly work-over as a minimum and the loss of a well was always a possibility. Failures occurred without warning and could happen with new materials within hours or days after installing. Engineers were faced with the problem of specifying materials for a service for which no reliable backlog of experience had been accumulated, and for which the normally used materials appeared unacceptable. To assist in arriving at early solutions to this problem, NACE Technical Unit Committee T-1G was organized in 1950 to make a cooperative study of the problem, the study to include collecting experience information and promoting field testing to gain additional information. As a long range project the committee is sponsoring research at Yale University under Professor W. D. Robertson on the basic metallurgical factors involved. This research is being financed by funds supplied from industry; both operators and suppliers have contributed.

This paper is intended as a progress report by this committee and will serve to define the present status of the sulfide corrosion cracking problem. Positive and detailed recommendations for preventing cracking failures cannot be given at this time. However, information has been obtained in the two-year period since the committee's initial progress was reported¹ which indicates the general approach that can be taken in working out specific preventive measures. Successful experience with certain preventive measures has been reported by operators, although the experience to date has been limited as to time and as to number of wells involved.

Scope of Problem

The type of failure with which this report is concerned is the failure by cracking of a metal when exposed under a tensile stress (internal or external) in a hydrogen sulfide environment. Controversy as to whether such failures are a form of hydrogen em-

Abstract

Field experience with sulfide corrosion cracking of production equipment, particularly tubing and casing, in sour gas-condensate and high pressure sour oil wells is summarized along with data from recent field tests. Preventive measures are described including selection of materials with minimum susceptibility to cracking and use of inhibitors. Laboratory and field test methods are reviewed.

General status of the sulfide corrosion cracking problem as it exists is described and future problems involved in very deep sour wells are considered.

brittlement or stress corrosion cracking or some combination has not been resolved.^{2,3,4} Therefore, the arbitrary term "sulfide corrosion cracking" has been selected by the committee to simplify discussion of field experience such as reported here.

The sour oil and gas fields in which sulfide corrosion cracking is a problem, and from which considerable operating experience has been gained, include Worland (Wyoming), Jumping Pound (Alberta) and McKamie-Patton (Arkansas). Others in which the problem is present, but from which there is only limited operating experience owing to the fact that the fields are in early stages of development include Pincher Creek (Alberta), Okotoks (Alberta), Ginger (Texas), Tinsley (Mississippi) and Lacq (France). The natural question is why the number of fields involved is so relatively small in comparison to the large number of sour fields. This can be answered partly by the observation that failures are encountered primarily with high strength materials, e.g., API grade N-80 or higher and, therefore, only deep wells, of which there are a limited number, are likely to be involved. In addition, it is known now

TABLE 1—Typical Well Characteristics in Four Fields Where Sulfide Corrosion Cracking Is a Problem

TYPE	GAS CONDENSATE			OIL
	Pincher Creek	Jumping Pound	McKamie-Patton	Worland
Well depth, ft.....	12,400.	10,500.	9,200.	10,500.
Wellhead pressure, shut-in, psig.....	3,200.	3,000.	2,500.	1,200.
Bottom hole temp., °F.....	188.	175.	230.	142.
Wellhead temp., flowing, °F.....	96.	80.	165.	85.
Gas production, MMCF/D.....	7.5	5.	5.	1-5.
Oil production, B/D.....	300.	70.	300.	100-600.
Water production, B/D.....	7.5*	3.	<1.	0-400.
Gas analysis, percent H ₂ S.....	10.	3.5	6.5	30.
percent CO ₂	6.	6.	3.	1.5

* After cement plugback from 12,700 to 12,400 feet.

* This report prepared by R. S. Treseder, Shell Development Co., Emeryville, Cal., chairman.

that well fluids vary in severity in promoting sulfide corrosion cracking so that conditions in every sour well may not be conducive to cracking. The latter point is discussed in greater detail later. The experience at Worland indicates that the problem exists in crude oil wells as well as in gas wells.

Well characteristics in several fields where sulfide corrosion cracking is a problem are summarized in Table 1.

Factors Involved

Whether or not a material fails due to sulfide corrosion cracking depends on the interaction of three main factors: The relative susceptibility of the material to cracking, the severity of the environment and the severity of the mechanical stresses to which it is subjected. For example, if a group of specific materials were tested under the same nominal high stress conditions in an environment classified as mild, only the most susceptible materials, e.g., very hard 12% chromium steel or hard 9% nickel steel, would be expected to fail. If the same series of materials were exposed in a more severe environment, additional materials, perhaps including steels meeting API grade N-80 specification, would fail. Conversely, if a series of materials were exposed to the same environment, with variations made in the magnitude of tensile stress applied, differences would be observed in the minimum stress required to produce cracking. It is by tests of the two types described above, i.e., tests under different environmental conditions or tests at different stress levels, that materials can be classified as to susceptibility to cracking.

The following discussion of the influence of these three factors is intended to provide a general orientation with respect to this problem and is based largely on information presented at the Galveston symposium by Bowers, McGuire, and Wiehe,² Fraser and Treseder,³ and Prange,⁴ and the earlier paper by Vollmer.⁵ For simplicity these factors are discussed separately, but all three must be considered together in evaluating any given situation.

Metallurgical Factors

Generally speaking, changes in a metal which cause an increase in mechanical properties, e.g., hardness and yield strength, tend to cause an increase in susceptibility to cracking. However, field and laboratory tests have shown that there is no well defined critical value of hardness or other mechanical property at which any marked change in degree of susceptibility occurs.

Failures have been experienced with N-80 tubing and casing, 9% nickel steel tubing, hardened 12% chromium steel valve parts, some carbon steel fittings and with both carbon steel and stainless steel (Types 304 and 316) wire lines. Under very severe laboratory test conditions, it has been possible to cause failure by cracking of all the alloys commonly used for oil well tubular goods with mechanical properties equal to or higher than API grade J-55. There are indications that Monel, K-Monel, Inconel, some austenitic stainless steels and perhaps other such alloys may be resistant to cracking in hydrogen sulfide environments.

Significant variations in susceptibility are observed in commercial materials which might be presumed to be quite similar. These variations in susceptibility are associated apparently with relatively minor changes in chemical composition, heat treatment and degree of mechanical working. In discussing field or laboratory sulfide corrosion cracking test results, it is essential to define as completely as possible the composition and metallurgical history of the material involved. This is particularly true with a material such as API grade N-80, which is made to certain mechanical property specifications with essentially no control on composition. Thus, it is possible to meet N-80 specifications with a large number of materials varying in both composition and heat treatment. Wide variations in resistance to sulfide corrosion cracking would be expected with such materials.

Environmental Factors

All well environments involving hydrogen sulfide can be considered as potentially able to promote sulfide corrosion cracking but the severity of different environments may vary owing to a number of factors associated with production characteristics which are not as yet well defined.

It appears that a water solution of hydrogen sulfide is the environmental factor needed to cause cracking. However, the obvious variables in this system, i.e., hydrogen sulfide concentration (partial pressure of hydrogen sulfide in gas) and temperature are also important. The minimum concentration of hydrogen sulfide required to produce cracking of a very susceptible material has not been defined, but apparently is quite low. It appears from some operating experience and from limited laboratory data that the tendency of a given environment to promote cracking diminishes with increasing temperature. Among other significant chemical and physical factors in the environment are acidity and oil wettability. The environment becomes more severe with increasing acidity and, as in the case of most oil well corrosion problems, an increase in the relative wettability of the produced oil for the metal surface decreases the tendency for attack to occur.

It has been shown that the ferrous sulfide film that forms on steel surfaces exposed to hydrogen sulfide environments can protect stressed specimens from cracking and that subsequent removal of the coating can lead to failure. Changes in environmental conditions that would have such an effect, therefore, would be expected to increase the severity of the system.

Insufficient field data have been obtained to allow any translation of the above into predictions of severity of environment defined in terms of characteristics of individual oil wells. Sulfide corrosion cracking conditions exist presumably in any well producing hydrogen sulfide. In view of the generally better wetting characteristics of crude oil as compared to condensate, cracking failures would be expected to be less likely in crude oil wells than in gas-condensate wells, other factors being equal. Variations in production characteristics of an individual well during its life may influence the tendency to promote crack-

observed presumed susceptibility to minor environment and field or results, it is possible the material material to certain essentially possible to er of treat- corro-materials.

ing. For example, acidization might increase the severity of the environment for a brief period. Also shut-in periods might be more severe due to lowering of temperature, if the temperature effect noted above is pronounced.

It appears that individual well tests with stressed specimens of known relative susceptibility would be required to define the degree of severity of a particular environment. Unit Committee T-1G is encouraging individual operators to make such tests and is considering at this time the idea of adopting standardized test procedures to be used. As more field data of this type become available, it may be possible to classify wells as to severity on the basis of the usual well data.

Mechanical Factors

As in the case of stress corrosion, failure by sulfide corrosion cracking requires significant tensile stresses, either applied or internal or both. In those few field failures which have been investigated in detail, the calculated applied stresses have been below the yield strength of the material involved (e.g., 57,000 to 89,000 psi in Case No. 1,¹ and 46,000 psi in Case No. 12 below). However, in laboratory and field testing with strip type specimens of similar materials loaded as beams, it has been necessary in most cases to stress the specimens to values near the yield strength or somewhat beyond in order to obtain failures in a reasonable time. It is not known whether this difference results from the additional effect of internal stresses in the field equipment or from the more complex applied stresses which are involved, including perhaps local stress raisers. Another significant point of difference is that in field and laboratory testing with beam type specimens stress application is of the constant deformation type, whereas with field equipment the stress generally is of the constant load type. Limited laboratory testing has shown the latter to be more severe at the same nominal maximum tensile stress.

It has been shown by considerable laboratory data and confirmed by field experience that cold-working tends to increase the susceptibility to cracking of a given alloy.

It is generally agreed that applied tensile stresses should be kept to a minimum practical value and that internal stresses be minimized by whatever means, e.g., stress relieving heat treatment, that are feasible for the particular equipment item.

Test Methods

Laboratory test methods previously used in studying sulfide corrosion cracking have been described previously.^{2,3,4} Strip type specimens, stressed as a simple beam with either one or two point loading

are used most commonly. Specimens are immersed in aqueous hydrogen sulfide solution for a definite time period or until failure occurs. Severity of the test is varied by increasing the acidity of the solution by addition of acetic acid, by increasing the applied stress on the specimen or by both methods. Use of U-bend specimens is becoming less popular owing to the severe cold-working involved. Cold-working is present in many of the beam tests, but it is done to a lesser degree and under more easily reproduced conditions. Since sulfide corrosion cracking tests are essentially "go" or "no-go" tests, there is a need for a semi-quantitative way of expressing results so as to allow comparisons to be made of different materials. Time to failure is not considered to be an entirely suitable way of doing this. The trend is toward making such comparisons by making tests of definite duration under conditions of varying severity, e.g., varying stress levels. Test reproducibility appears to be such that multiple testing is required for accurate comparisons.

Field test methods employ the same type specimens as employed in laboratory tests and specimens are usually inserted in the flowline near the wellhead. Additional design features are required in order to prevent movement of specimen in the bowline. The same factors mentioned above enter into field testing also. The minimum time generally used in such tests has been two weeks and the maximum time may range up to several months.

As was mentioned above, Unit Committee T-1G is considering the standardization of laboratory and field test methods.

Field Test Data

Data obtained during the second committee-sponsored field test at McKamie-Patton are summarized in Table 2. The essential difference between this and the previous test¹ was the inclusion in the second test of stressed specimens of materials known to have a very high degree of susceptibility to cracking.

TABLE 2—Summary of Second Field Test at McKamie-Patton

ALLOY*	Yield Strength, psi	Ultimate Strength, psi	Rockwell Hardness, C Scale	Prestress (Tensile), psi	TEST RESULTS*	
					Gulf Type ^c	Shell Type ^c
APIJ-55.....	54,000	92,000	(53A)	.....	.....	00
API N-80.....	91,000	118,000	21	.....	.....	00
API N-80.....	104,000	130,000	22	.....	.....	00
API N-80.....	94,000	126,000	23	.....	.....	00
API N-80.....	83,000	116,000	20	.....	.....	None of 10
API N-80.....	101,000	125,000	25	120,000	00	.....
P-110.....	119,000	136,000	30	135,000	00	.....
5 percent Ni steel.....	66,000	99,000	(54A)	.....	.....	00
9 percent Ni steel.....	106,000	126,000	24	.....	.....	None of 18
9 percent Ni steel.....	145,000	171,000	31	.....	.....	XX00
7 percent Cr steel.....	126,000	158,000	30	.....	.....	00
9 percent Cr steel.....	158,000	185,000	38	.....	.....	0000
SAE 4140.....	155,000	165,000	36	165,000	00	.....
SAE 4140.....	130,000	148,000	30	.....	.....	0000
SAE 4340.....	126,000	148,000	27	.....	.....	None of 14
AISI Type 410.....	.....	.....	20	.....	.....	0000
AISI Type 410.....	.....	.....	30	.....	.....	0000
AISI Type 410.....	.....	.....	45	.....	.....	X000
AISI Type 322.....	156,000-174,000	188,000-203,000	40-45	175,000-203,000	All of 7	.....

* Composition and heat treatment of alloys tested are given in Table 3.

^b X = failure by cracking; 0 = no failure. Exposure time varied from 2 to 12 weeks. All failures reported occurred within 2 weeks.

^c See Reference 1 for detailed description of specimens and manner of loading. All Shell specimens had stress raisers.

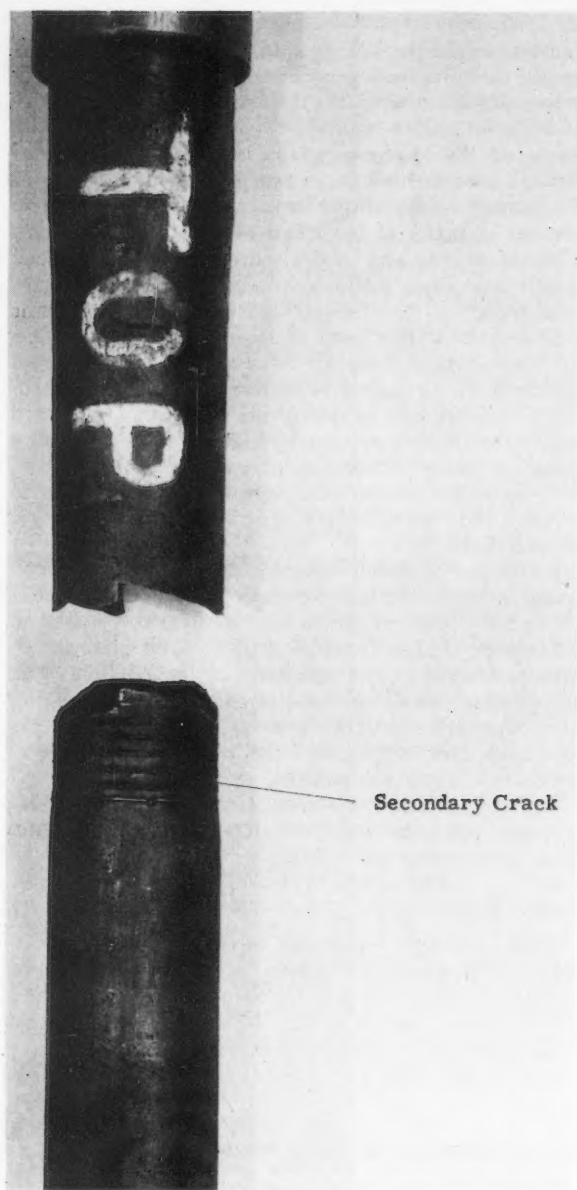


Figure 1—Failed joint of N-80 tubing from Jumping Pound. (Case No. 12)

Some of the latter materials failed in this second test. Those materials which failed included Stainless 322 (age hardened), 9% nickel steel (very high mechanical properties) and 12% chromium steel (quenched and tempered to Rockwell C 45). None of the ordinary tubing materials, such as API grade N-80, or other moderately susceptible materials, as defined by previous field and laboratory tests, e.g., quenched and tempered SAE 4340, failed in this second test. Thus, it could be concluded that the McKamie-Patton test conditions were less severe than the other test sites, i.e., Jumping Pound and Pincher Creek. This conclusion is confirmed by field experience. These field test data also indicate that susceptibility to sulfide corrosion cracking correlates with mechanical properties in a general way only, and that the precise correla-



Figure 2—Another view of failed tubing from Jumping Pound.

tions are not possible, e.g., the 9% nickel steel that failed had lower mechanical properties than 9% chromium steel that did not fail.

Weight loss corrosion data obtained during this second test confirmed the earlier test data in showing negligible corrosion (less than 1 mil/yr for 12 weeks' exposure) of all materials tested.

Field Experience

Additional field experience has been obtained since that reported two years ago. This is summarized below. The numbering is a continuation from that used in the previous report on this subject.¹

No. 10

Failed item—N-80 casing (7-inch, 26 lb, LT&C).

Well location—Worland Field, Wyoming.

Well information as in Table 1.

Description of failure: Casing had been in service two years when failure occurred; casing recovered four years after failure. Exact conditions at time of failure not known. Failure occurred at 2000 feet. Extreme longitudinal and lateral cracking throughout the entire length of several casing joints; casing collars were split. Fractured surface had brittle appearance. Cracks were intergranular, multiple and highly branched. Microscopic secondary cracks observed.

No. 11

Failed items—N-80 tubing (2½-inch EUE). Total of five failures.

Well location—Worland Field, Wyoming.

Well information as in Table 1.

**TABLE 3—Composition and Heat Treatment of Alloys
Used in Second McKamie-Patton Test**

Alloy ^a	Composition	Heat Treatment ^b
API J-55	0.40 C, 0.72 Mn, 0.02 S, 0.003 P, 0.14 Si	Mill
API N-80	0.40 C, 1.57 Mn, 0.03 S, 0.17 P, 0.15 Si, 0.22 Mo	Mill normalized
API N-80	0.42 C, 1.75 Mn, 0.03 S, 0.019 P, 0.25 Si, 0.18 Mo	Mill normalized
API N-80	0.49 C, 1.45 Mn, 0.04 S, 0.019 P, 0.26 Si, 0.42 Mo	Mill normalized
API N-80	0.38 C, 1.31 Mn, 0.02 S, 0.007 P, 0.25 Si, 0.31 Mo	Mill normalized
API N-80	0.41 C, 1.83 Mn, 0.014 S, 0.022 P, 0.25 Si, 0.22 Mo	Mill normalized
P-110	0.28 C, 1.40 Mn, 0.032 Si, 0.020 P, 0.003 B	Mill Q and T
5 percent Ni steel	0.12 C, 0.46 Mn, 0.013 S, 0.016 P, 0.23 Si, 4.9 Ni	Mill
9 percent Ni steel	0.08 C, 0.39 Mn, 0.023 S, 0.018 P, 0.19 Si, 8.8 Ni	Mill
9 percent Ni steel	0.11 C, 0.5 Mn, 8.8 Ni	Mill
7 percent Cr steel	0.09 C, 0.41 Mn, 0.008 S, 0.018 P, 0.70 Si, 6.7 Cr	Mill
7 percent Cr steel	0.09 C, 0.35 Mn, 0.008 S, 0.018 P, 0.33 Si, 8.4 Cr, 0.91 Mo	Mill
SAE 4140	0.42 C, 0.37 Mn, 0.019 S, 0.013 P, 0.25 Si, 0.20 Mo, 0.18 Ni, 0.92 Cr	1550° F. OQ, T 975° F
SAE 4140	(Not Analyzed)	1575° F. OQ, T 1100° F
SAE 4340	0.33 C, 0.71 Mn, 0.010 S, 0.010 P, 0.25 Si, 0.30 Mo, 1.64 Ni, 0.75 Cr	Mill
AISI Type 410	0.12 C, 0.45 Mn, 0.012 S, 0.019 P, 0.46 Si, 0.04 Mo, 0.18 Ni, 12.3 Cr	1800° F. OQ, T 1100° F
AISI Type 410	0.12 C, 0.45 Mn, 0.012 S, 0.019 P, 0.46 Si, 0.04 Mo, 0.18 Ni, 12.3 Cr	1800° F. OQ, T 1000° F
AISI Type 410	0.12 C, 0.45 Mn, 0.012 S, 0.019 P, 0.46 Si, 0.04 Mo, 0.18 Ni, 12.3 Cr	1800° F. OQ, T 750° F
AISI Type 322	0.07 C, 0.50 Mn, 7.0 Ni, 17.0 Cr, 0.70 Ti, 0.20 Al	AH 950° F

^aAlloys are listed in same order as in Table 2.^bQ-quench; OQ-oil quench; T-temper; AH-age hardened.

Description of failure: Tubing parted in body of joint, not at upset. Failures generally occurred when well was shut in. Examination showed multiple, highly branched transgranular cracks with microscopic secondary cracks.

No. 12

Failed item—N-80 tubing (2½-inch EUE).

Well location—Jumping Pound Field, Alberta.

Well information as in Table 1.

Description of failure: Failure occurred while well was shut in following potential flow test pending completion of flowline. Failure was one foot from top of joint (see Figure 1) at depth of 1429 ft. Estimated applied tensile stress at point of failure was 46,000 psi. Tubing had been in well two weeks at time of failure. Inhibition had not been started in well at time of failure.

Fracture was both brittle and ductile (see Figure 2). Cracking was primarily transgranular. There were at least four cracks; some branching observed in one crack. Secondary crack observed below main crack.

Analysis: 0.49 C, 1.45 Mn, 0.019 P, 0.041 S, 0.26 Si, 0.42 Mo. Mechanical properties: Hardness, 23 Rc; 84,000 psi yield strength, 125,000 psi ultimate strength; 56% reduction of area, 23% elongation.

Note: A second failure of N-80 tubing has been experienced recently at another well in this field. Examination is in progress, but it is not established as yet whether the failure was due to sulfide corrosion cracking.

No. 13

Failed item—carbon steel bull plug (2-inch).

Well location—Okotoks Field, Alberta.

Well type—sour gas-condensate.

Well depth—8400 ft.

Well head pressure, shut-in—2300 psig.

Bottom hole temperature—175° F.

Wellhead temperature, flowing—90° F.

Gas production, MMCF/D—3.

Distillate production, B/D—9.

Water production, B/D—4.

Gas analysis—33% H₂S, 10% CO₂.

Description of failure: Bull plug was in flowline and failure occurred while pressuring prior to flowing the well. There were four radial cracks which started from inside wall of the plug. Cracks were transgranular and branching. Applied stress was low but there was possibility of appreciable internal stresses due to wrench damage.

Analysis: 0.04 C, 0.23 Mn, 0.016 P, 0.002 S, 0.01 Si.

Mechanical properties: Hardness, 52 Rc; 77,000 psi yield strength, 82,000 psi ultimate strength; 68% reduction of area, 19% elongation.

No. 14

Failed item—Wire lines (numerous cases).

Steel wire line failures have been reported by several operators. Failures have occurred after 4 to 6 hours' exposure to well fluids.

Type 304 and Type 316 wire line failures have been reported by at least two operators.

The significant observation from the above summary is that failures have occurred with N-80 tubing and casing in sour gas-condensate and crude oil wells under what could be considered as normal operating conditions. In the one instance where failed tubing is known to have been examined in detail, there was no indication of any abnormalities in structure, composition, or mechanical properties of the tubing material. Also significant is the observation that low carbon steel equipment failed in one instance (Case No. 13). The wire line failures of both carbon steel and the stainless steels are not surprising in view of the severe cold-working involved in fabrication of these items.

Preventive Measures

The preventive measures currently in use by various operators are summarized below. It should be emphasized that the time these measures have been in use is relatively short in most cases and the number of wells involved is low. Hence, it may be too early to reach conclusions regarding the success of individual measures.

I. Worland Field

Casing. N-80 used. Annulus is packed off to protect casing from well fluids. Where oil is circulated in annulus organic inhibitor is added periodically (one gallon/month). One failure occurred prior to addition of inhibitor. Insufficient time since to judge effectiveness.

Tubing. N-80 used. In view of past experience in which failures have coincided with shut-in periods, circulation of hot oil in the annulus is maintained (depth, ca. 3500 ft.) during all shut-in periods; input temperature of oil = ca. 155 degrees F. Five tubing failures prior to inauguration of temperature maintenance program. Insufficient time since to judge effectiveness of change.

Wellhead. Fittings are carbon steel. Valves are

carbon steel gate valves with Type 316 stainless steel trim. No failure reported that could be attributed to sulfide corrosion cracking.

Wire Lines. Use carbon steel lines wiped with concentrated organic inhibitor plus careful inspection prior to running. This procedure has been successful.

II. Jumping Pound Field

Casing. N-80 and J-55 used. Annulus packed off. Oil circulated in annulus in some cases. No casing failures reported since early failure (Case No. 4¹) prior to adopting practice of using packers.

Tubing. N-80 and J-55 used (2½-inch EUE). In view of two failures experienced with N-80 tubing are changing over to J-55 in all wells. Stress in tubing reduced by setting tubing on packer. Organic inhibitor added daily to wells at rate of 0.5 stick/MMCF. Inhibition program started with initial production from field.

Wellhead. Fittings are equivalent of N-80 grade. Valves are equivalent of N-80 type steel with chrome plated gates. No failures attributable to sulfide corrosion cracking reported.

Flowlines. Grade A or B seamless (2-inch XXH) line pipe. No failures reported.

Wire Lines. Use steel with liquid organic inhibitor wiped on. This procedure has been successful.

III. McKamie-Patton Field

Casing. J-55 and N-80 used. Annulus packed off. No cracking failures.

Tubing. J-55 and N-80 used. No cracking failures. Experienced two failures with 9% nickel steel tubing, one sub and one pup joint (see Case No. 2 and No. 3¹).

Wire Lines. Have experienced failure of Type 304 and Type 316 stainless wire lines. Liquid organic inhibitor wiped on lines has given satisfactory service.

IV. Pincher Creek Field

(Wells have not been produced except for test purposes.)

Casing. N-80 used. Annulus packed off.

Tubing. N-80 selected to have less than 90,000 psi yield strength. Integral joints used. Tubing coated with phenolic type coating on inside. Tubing set on packer to minimize stresses. One double failure of 9% nickel steel observed in this field (see Case No. 1¹) prior to establishing above practices.

Summary

From the cases described above, it appears that the problem of sulfide corrosion cracking is being brought under control. Casing is protected by packing off the annulus and by carefully selecting the fluids placed in the annulus. No serious failures have been reported recently with standard wellhead equipment, although precautions have been taken to avoid using extremely susceptible materials. The greatest degree of uncertainty regarding preventive measures is associated with tubing.

Current thinking of operators regarding preventive measures for tubing follows the general pattern of 1) selecting materials of maximum resistance to cracking, 2) keeping applied stresses to a minimum and, 3) employing such secondary measures as inhibitors and protective coatings.

Selection of J-55 tubing in preference to N-80 appears to have provided a satisfactory answer in those instances where mechanical requirements permitted such a selection. N-80 tubing apparently should be used with caution in wells where severe sulfide corrosion cracking conditions exist. Owing to the wide variability of N-80, there is hope that selection of specific heats based on some established criterion may provide materials of adequate resistance to cracking. It may be that more positive improvement in the resistance of N-80 will be required, such as might be accomplished by additional heat treatment or by control of composition. This subject is under active investigation now by individual companies. With the deeper sour wells of the future, which will require tubing materials with higher mechanical properties than N-80, the problem of selection of resistant materials may become much more difficult. It is hoped that the current fundamental research at Yale will provide information of value to the long range development of high strength materials of maximum resistance to sulfide corrosion cracking.

Specifications for materials selected for sour gas and oil wells where sulfide corrosion cracking is a problem may have to be much more detailed than is common now in the oil production industry. Also, in selecting materials, it may be necessary to make allowances for unforeseen variations in manufacture and application. This would involve selecting materials of higher resistance to cracking than that indicated by test to be required.

It is generally agreed that tubing stresses should be reduced by setting as much of the tubing weight as possible on the packer. Maintenance of hot oil circulation during shut-in periods as practiced at Worland may be helpful in reducing stresses in addition to possible effects in reducing the severity of the environment.

In fields where severe conditions exist, operators favor use of secondary measures such as inhibition or coatings as added protection against failure, particularly if a marginal material such as N-80 is employed. However, these secondary methods cannot be used with complete assurance. With inhibition there is the problem of providing inhibition all of the time; the obvious periods when inhibition is difficult are during well completion and during shut-ins. Apprehensions are felt regarding coatings owing to the probable limited life and possibility of failure at holidays.

To provide the knowledge required for sound engineering solutions to this severe problem, continued intensive study of this problem on a cooperative basis is needed. Of particular value will be additional experience information of the type reported above. Operating companies are invited to submit such information to the committee.

Acknowledgment

Progress of the Committee's work has been made possible by the active cooperation of the individual committee members and the willingness of the companies represented to submit information to the committee.

References

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2. C. N. Bowers, W. J. McGuire and A. E. Weihe. Stress Corrosion Cracking of Steel Under Sulfide Conditions. *Corrosion*, **8**, No. 10, 333-341 (1952) Oct.
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4. F. A. Prange. Hydrogen Embrittlement Tests on Various Steels. *Corrosion*, **8**, No. 10, 355-360 (1952) Oct.
5. L. W. Vollmer. Hydrogen Sulphide Corrosion Cracking of Steel. *Corrosion*, **8**, No. 10, 326-332 (1952) Oct.

DISCUSSION

Question by Loren L. Neff, Union Oil Company of Cal., Brea, Cal.:

Does sulfide corrosion cracking usually occur immediately after the well is completed?

Reply by R. S. Treseder:

In most of the cases that have been reported to the committee, failure has occurred in a relatively short time after the well environment came in contact with the equipment item. There have been a few exceptions (see Item 11 under "Field Experience"), but it is possible these may have been associated with operational changes that would have led to a change in environment or stress conditions.

Question by E. D. Weisert, Kokomo, Ind.:

What is known about the mechanism of sulfide corrosion cracking? What are the laboratory methods of testing for this type of corrosion?

Reply by R. S. Treseder:

There is some uncertainty as to the mechanism of sulfide corrosion cracking. Some believe it to be a form of hydrogen embrittlement, others think it is stress corrosion cracking and others believe in a mechanism involving a combination of the two. For a detailed discussion of this and for descriptions of laboratory test methods, see References 2, 3 and 4.

Question by Andrew Dravnieks, Standard Oil Co. of Indiana, Whiting, Ind.:

What is the present thinking on relation between Rockwell hardness and frequency of cracking?

Reply by R. S. Treseder:

Generally speaking, increased susceptibility to cracking is associated with increased Rockwell hardness. However, laboratory and field experience reported in this paper and elsewhere shows that hardness alone is not a safe criterion to use, especially in comparing materials of different composition or materials of the same composition subjected to different types of heat treatment. Hardness could be useful, perhaps as a criterion in the case of a given material subjected to minor variations in heat treatment, e.g., a material quenched and then tempered at various temperatures.

DISCUSSIONS ON TECHNICAL ARTICLES ARE SOLICITED

Discussions on technical articles published in *Corrosion* will be accepted for review without invitation. Discussions must be constructive, accompanied by full substantiation of fact in the form of tables, graphs or other representative data and be submitted in three typewritten copies.

Authors of discussions are asked to supply one copy of figures suitable for reproduction and will be sent on request a copy of the NACE Outline for the Preparation and Presentation of Papers.

Discussions will be reviewed by the editor of *Corrosion* and will be sent to the author of the paper discussed for his replies, if any. Publication will be in the Technical Section with full credit to the authors together with replies. Discussions to papers presented at meetings of the association may be submitted in writing at the time of presentation or later by mail to the editorial offices of *Corrosion*, 1061 M & M Bldg., Houston 2, Texas.

Passing of the Stray Current Problem*

By ROBERT H. POPE*

SOME TIME around the middle or late 1920's trolley development reached its peak. The Connecticut Company had a network of trolley lines in Connecticut and Public Service had plans for high speed lines in New Jersey. Rights-of-way acquired for some of the proposed lines were not used however because the era of trolley lines began to wane. Most of these unused rights were taken over for electric transmission lines.

Many city streets had trolley lines on them. Some like Canal Street in New Orleans and Park Row in New York had more than one set of tracks. In Manhattan, New York City and San Francisco underground traveling cables were used to propel cars before the days of electricity. With the advent of electric traction the street slots formerly used for the cable were used to conduct electricity to the cars by means of underground buses. A shoe on the bottom of the car made contacts with positive and negative feeders. This eliminated the use of overhead trolley wires which are prohibited by law in some places. When New York tried using chemicals for melting snow the trolley company objected because the solution got into the street car slot and practically shorted the feeders.

Interurban lines were also highly developed. An interurban trolley guide with time tables was published and it was possible to go from Boston to Washington entirely by trolleys. Many other lines were established between cities where traffic justified them. Interurban lines were the first to feel the pinch of auto competition.

By 1930 trolley lines began to disappear and the entire problem of underground corrosion changed. When these lines discontinued operation, the beneficial effect of trolley current in providing a measure of cathodic protection was realized. In some cities movements were started to set up large generators to create earth currents to continue these benefits and in at least one case the defunct trolley company

was supposed to operate such a system without compensation.

In addition to underground plant which was losing the beneficial effects of trolleys, plant was being installed in areas never affected by trolleys. Outstanding in this class are the long gas, gasoline and oil transmission lines and long distance underground telephone cables.

An interesting case of the effect of trolleys occurred at Naamen, Delaware. Underground telephone cables were paralleled by a trolley line between Chester, Pennsylvania and Wilmington, Delaware. Ordinarily, at a mid-point between generating stations, underground structures would get some cathodic protection from the trolley line. In this case, however, the cables passed under Naamen Creek which flowed into Delaware River. Apparently the creek and river provided a low resistance earth path back to the grounded negative bus of the trolley generators at Chester. The stray traction current picked up by the underground cables left them at the creek crossing for the water route to Chester. This created a stray current exposure remote from the generators. A drainage wire to the Chester bus was impractical because it would have to be enormous to compete with the water conductivity. A wire to Chester with a booster generator was considered but this led to the reasoning that if the current wanted to use the water route, why not put it into the water? A ground was established in the creek bed and a new type source of d-c, known as a copper oxide rectifier, was used to force the current through this ground connection. A trial installation was made on April 26, 1927 and a regular installation was made on April 10, 1928. Because this device was used in place of the boosted drainage to the Chester bus, it was not illogical to call it forced drainage. The term "forced drainage" has been widely used in the Bell System but has not been accepted generally. In the early days, it was essential to use an expression which definitely differentiated between stray current cathodic protection and rectifier type cathodic protection. Could rectifier-and-sacrificial-anode protection be called "rasap"?

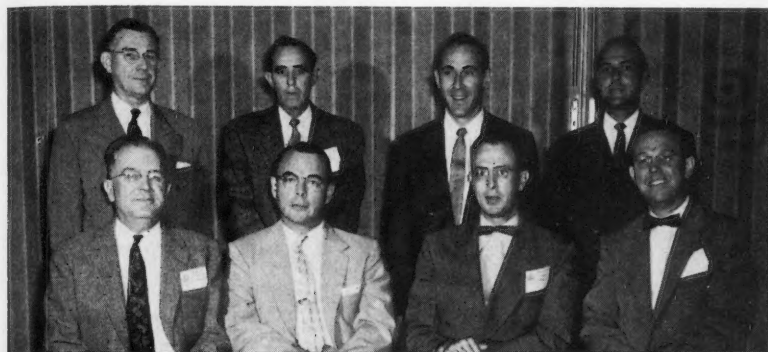
* The fifth in a series of six articles on early developments in cathodic protection and corrosion mitigation measures on underground and underwater structures.

* Formerly with Bell Telephone Laboratories, Murray Hill, N. J., now Box 231, Quakertown, R.D. 4, Pa.



NACE News

Attendance Record Broken at Dallas Meeting



Intense Interest Is Shown in Symposia, Committee Sessions

Intense interest in symposia presentations and meetings of technical committees was evidenced by the very heavy attendance at Dallas October 2-15. The South Central Region NACE meeting held at Hotel Adolphus had 555 registered for the technical sessions and 75 ladies for the program arranged especially for them. This was a new record, exceeding the number at Tulsa in 1953.

The annual banquet October 14 was attended by 180 more persons than had been expected from a statistical computation. Entertainment was enjoyed and dancing attracted many.

R. L. Thornton, Sr., mayor of Dallas, president of one of the Southwest's largest banks and head of the State Fair of Texas was speaker at the annual business luncheon held October 15.

Eight symposia were presented, mostly on subjects related to the petroleum and petrochemical industries. Technical committee meetings held Tuesday and Wednesday were well attended by both members and guests. The large number of committee meetings had resulted in extending the gathering an additional day.

Ladies' Program Is Attended by 76

Ladies' activities during the 1954 South Central Region meeting at Dallas October 12-15 were planned by Mrs. R. A. McCarty, whose husband is with Hill, Hubbell & Co., Dallas. The program planned by Mrs. McCarty for the 76 women registrants included a get-acquainted meeting, witnessing a showing of Cinerama, luncheon in the Adolphus Century Room, an ice show and sightseeing tours personally conducted by the ladies of North Texas Section NACE members.

Central Arizona Section's Petition Is Presented

Western Regional Division's board of trustees scheduled a meeting October 13 to act upon a petition for formation of the Central Arizona Section.

This petition, if approved, brings to 46 the number of sections in the NACE and to six the sections in the Western Regional Division.

Shreveport Section

J. F. Farmer of the DeVilbiss Company, Toledo, Ohio was scheduled to present a sound movie entitled "Making the Most of the Spray Painting Method" to the Shreveport Section, October 19 in the Caddo Hotel, Shreveport, Louisiana. Mr. Farmer was then scheduled to lead a discussion of this topic.

NORTHEAST REGION MEETING AT CHARLESTON—Top: Some regional and sectional officers present, left to right, back row, Dwight J. Bird, chairman Greater Boston Section; A. C. Hamstead, past-chairman, Kanawha Valley Section; Kempton, H. Roll, chairman Northeast Region; George Orr, chairman Kanawha Valley Section; front row, Conrad L. Wiegiers, treasurer; George W. Klohr, secretary; J. M. Bates, vice-chairman, all of Kanawha Valley Section and George E. Best, director, Northeast Region. Middle: Committee chairmen, Kanawha Valley Section, left to right, George C. Cox, publicity; R. I. Zimmerer, program; W. H. Williams, arrangements; R. G. Schroeder, membership. Bottom: View of audience during presentation of technical papers.

Three Papers Are Given at Charleston, W. Va.

The Kanawha Valley Section was host for the one-day fall regional meeting of the NACE Northeast Region in Charleston, W. Va. on September 21. C. E. Hodges, secretary of Charleston Chamber of Commerce, was guest speaker.

Three technical papers were presented during the one-day session attended by 89 members and guests.

Chromate for Corrosion Control In Methanol Antifreeze was the title of a

paper given by George E. Best, Mutual Chemical Co., Baltimore, Md., in which he described tests covering two winter seasons of automobile and truck operation with methanol antifreeze containing chromate with and without supplementary additions of borax, tetrasodium pyrophosphate or sodium metasilicate. Mr. Best revealed satisfactory inhibition and good stability of antifreeze solution were obtained using nominal additions of

(Continued on Page 2)

Maxwell Will Talk at Houston Student Night

When the Houston Section, NACE, holds its Annual Student Night Program November 9, Dr. H. L. Maxwell, E. I. du Pont de Nemours & Company, Inc., Wilmington, Del., shown here, will speak on Corrosion and the Undergraduate. Student representatives of the various engineering societies, together with faculty advisors, have been invited from Rice Institute, the University of Houston, University of Texas and Texas A & M.

Dr. Maxwell will tell the students that a corrosion engineering career is one of the most rewarding within their reach. Many chemical and petroleum plants today would be inoperable, economically, without the daily direction of skilled specialists in corrosion, according to Dr. Maxwell. Enormous investments in modern petroleum and process chemical plants emphasize the necessity for keeping those plants in continuous operation.

Corrosion science is a field unique in the engineering profession, according to Dr. Maxwell. The corrosion engineer uses as tools the basic sciences such as chemistry, physics and some geology; he also joins hands with the chemical and mechanical engineer, delving into the mysteries of chemical kinetics and



stress analysis and counter-EMF.

At the October 5 meeting, C. L. Woody, engineer for the United Gas Corporation, delivered a talk on instruments and gadgets in connection with cathodic protection work. Mr. Woody explained the development of the multi-use meters by showing how the basic instruments were combined. The instruments, both simple and complex, were on display. Simple language interspersed with humor made Mr. Woody's talk an interesting one.

Asphalt Coatings Topic At Denver Meeting

At the September 17 meeting of the Rocky Mountain Section held at the Olin Hotel, Denver, Colorado, approximately 30 members and guests heard Lloyd Bramble of the Gulf States Asphalt Company, Houston, Texas, speak on Asphalt Coating for Underground Structures. Mr. Bramble covered the subject of the formulations and applications of asphalt coatings for use on these structures.

The next meeting of the Rocky Mountain Section is scheduled for December 17 and an attempt is being made to arrange for a Short Course on Instrumentation in conjunction with this meeting.

Corpus Christi Section

Corpus Christi Section held its annual barbeque meeting at Humble Oil & Refining Company's Flour Bluff Camp September 25. There was no formal program at this meeting which families were invited to attend. About 75 persons were present.

ASTE Exposition Set

The first Western Industrial Exposition of American Society of Tool Engineers is scheduled to be held in Los Angeles, California in March 1955.

Three Papers —

(Continued from Page 1)

2000 ppm and 5000 ppm Na_2CrO_4 with pH above 8.0.

Uses of Stainless Steels In Process Industries presented by J. J. Heger, U. S. Steel Corp., Pittsburgh, Pa. asserted that the principal characteristic of stainless steels is good resistance to corrosion and that their successful use depends upon selection of suitable alloy, experienced fabrication, careful design to avoid localized corrosion and controlled operation of equipment. Mr. Heger said stainless steels should not be carelessly interchanged in different corrosive services or in conditions involving operating variables, especially temperature.

In Economics of Cathodic Protection W. R. Curley, Hope Natural Gas Co., Clarksburg, W. Va., discussed economic considerations of cathodic protection. He noted one approach to economics of coating is to compare current cost of protecting well-coated line to that of protecting bare line. If the ratio is 1 to 100 coating is justified, if it is 1 to 10 coating may not be justified. Mr. Curley recommends adequate surveys prior to pipe line construction and stressed the contention that installation of cathodic protection devices is a job for experienced corrosion engineers. Otherwise, he said it may be ineffective or adjacent structures may be damaged.

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E. G. BRINK, American Viscose Corp., who acted as moderator during a panel discussion at Philadelphia Section's panel discussion on corrosion October 8.

111 Participate in Philadelphia Discussion

The October 8 meeting of the Philadelphia Section consisted of a panel discussion of corrosion problems. The panel of experts representing the major fields of corrosion control activity answered questions submitted by the audience and was comprised of the following persons: E. G. Brink, American Viscose Corp.; J. J. Meany, Jr., A. V. Smith Engineering Co.; C. C. Sward, National Paint, Varnish & Lacquer Assoc.; G. E. Purdy, Tretolite Co.; S. W. Shepard, Chemical Construction Corp.

Interest in the meeting was indicated by the 111 members and guests present.

Portland Section Holds Pipe Corrosion Session

Approximately twenty members and guests attended the September 28 meeting of the Portland Section held at The Campbell Court Hotel, at which a panel consisting of P. G. Behr, R. T. Miller and C. A. Roberts of the Portland Gas and Coke Company discussed the subject Underground Pipe Corrosion Investigation and Protection. The panel also discussed the various electrical instruments used by corrosion engineers in corrosion investigation and cathodic protection work.

New Orleans-Baton Rouge To Hold Four Meetings

The New Orleans-Baton Rouge Section has scheduled the following meetings:

November 1—Corrosion Coupons and Fluid Analysis.

December 6—Panel Discussion: Well Corrosion Programs.

January 24, 1955—Corrosion Inhibitors and Injection Methods.

February 28—Internal Plastic Coatings for Tubing.

Cathodic Protection Is Genessee Valley Topic

Hillary Humble, with Dow Chemical Company, Midland, Michigan, spoke to approximately 40 members and guests of the Genessee Valley Section on September 27 on cathodic protection. Mr. Humble discussed the basic principles of cathodic protection. Practical applications were described using as illustrations such examples as hot water heaters, ship hulls, heat exchangers and industrial storage tanks. Mr. Humble's talk was followed by a lively discussion.

NACE's Western Region plans to hold two short courses each year. Attendance is not restricted to members of NACE.

Southwestern Ohio Has Visit to Soap Plant

First meeting of the Southwestern Ohio Section for the 1954-55 season consisted of a visit to the plant of the Procter & Gamble Company. The 40 members and guests attending the meeting were first shown a movie about the general operations of Procter & Gamble after which they were conducted on a tour of the plant and shown some of the soap making and other facilities. The tour was followed by a meeting at Shuler's Restaurant in Cincinnati and a general discussion of the afternoon's activities led by George Lockman and W. R. Hoskins of the metallurgical department of Procter & Gamble.

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Corrosion Engineer—Graduate engineer with field and design experience in cathodic protection systems. Extensive travel. Salary open. Harco Corp., P. O. Box 7026, Cleveland 28, Ohio.

Metallurgist—Corrosion and/or electroplating experience required to supervise metallurgists and chemists in research and development of aircraft materials. Salary \$5940 or \$7040 per annum. Write Naval Air Material Center, Naval Base, Philadelphia 12, Pa.

Manager—To manage reorganized department for sale of corrosion-proof materials. Good understanding of corrosion-proof materials or construction and sales experience in this field necessary. Location Cleveland. Write full details. CORROSION, Box 54-22.

Sales Engineers—Promotions make possible openings to manage New York and Chicago sales offices for manufacturer of corrosion-proof process equipment. Outstanding opportunity for young engineer with sales experience in this area with the chemical, steel and electroplating industries. Write full details. CORROSION, Box 54-23.

Corrosion Engineer or Chemist—Recent graduate with electrochemical background. Knowledge of metallurgy desired but not required. Work on corrosion problems for major oil company, New York City. Write CORROSION, Box 54-24.

Corrosion Engineer—Graduate engineer with responsible field and design experience in cathodic protection systems for marine craft. Salary: \$8360-\$9360. Some travel with per diem. Write Marietta Transportation Depot, Marietta, Pa. for details.



SAN DIEGO SECTION'S meeting September 15 heard Dave Jones, Construction Supervisor, Pacific Telephone and Telegraph Co. (seated, left) and Roy E. Dodson, Superintendent of Water Production, San Diego Water Department (seated, center) on the technical program. D. P. Armbruster, San Diego Gas and Electric Co. (standing), chairman, presided.

40-Months' Tests on Hot Water Heaters Reported by Dodson

Roy E. Dodson, Superintendent of Water Production, San Diego Water Department, presented a paper on Hot Water Heater Corrosion and Dave Jones, construction supervisor, Pacific Telephone and Telegraph Co., discussed Telephone Company Grounding in Relation to Underground Piping at the September 15 meeting of San Diego Section, NACE.

Mr. Dodson described test runs on popular brand, galvanized steel domestic water heaters by the water heater testing laboratory of San Diego Water Department. He revealed the test was accelerated by maintaining temperature

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at 150 degrees F and arranging automatically controlled solenoid valves to discharge approximately five gallons of water per heater every hour, 24 hours a day during a 40-month test period. Mr. Dodson explained heaters were cathodically protected with and without impressed voltage and were subjected to various types of water as follows: filtered and chlorinated, lime treated to maintain high pH, phosphate treated, zeolite softened and untreated for control. He said heaters were cut open and inspected at end of test and that consensus was that cathodic protection without impressed voltage was most practical method for these types of heaters.

Mr. Jones discussed various means and protectors used by telephone companies to ground telephone circuits to underground piping.

San Diego Section's membership has increased to 32.

Process Equipment Is Sabine-Neches Topic

Thirty-five members and guests of the Sabine-Neches Section heard Charles H. Homer of the American Locomotive Company, Beaumont, speak on the subject of Quality Factors in the Fabrication of Process Equipment at the September 30 meeting of the section, held in the Elks Lodge at Port Arthur, Texas. Mr. Homer discussed the responsibilities of the fabricator and the purchaser in the design of process equipment and pointed out that while the fabricator assumes the responsibility for the quality of materials and workmanship, the purchaser must assume the responsibility for selection of materials for corrosion resistance. He also discussed the various designs of heat exchangers and the various materials used and their relative costs and pointed out that fabrication techniques and heat treatment are important factors in the corrosion resistance of process equipment.

Permian Basin Section Hears Williams Talk

Jack Williams of the National Tank Company, Odessa, Texas, spoke to 45 members and guests at the October 4 meeting of the Permian Basin Section in the Cave Room of the Lincoln Hotel, Odessa on the subject of Corrosion in Production Equipment.

During the business portion of the meeting Ed Ray announced that the arrangements for the Permian Basin Booth to be operated during the forthcoming oil show in Odessa were nearly complete. The report on the Fifth Biennial Corrosion Tour held in 1953 is scheduled to be released within the week.

The nominating committee also reported a slate of officers for chairman, first and second vice chairman and secretary-treasurer for 1955.

The Inter Society Corrosion Committee has representatives from more than 30 organizations.

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Pittsburgh Section Sets Programs Through May

Fifty-five members and guests heard B. J. Philibert, Mathieson Chemical Co., speak on A Practical Corrosion Service Program during the October 7 meeting of Pittsburgh Section at the Royal York Hotel in Pittsburgh, Pa. Ellis Verink, Jr., Aluminum Company of America, is program chairman and J. H. Royston, Royston Laboratories, Inc., continues as entertainment chairman of the section which now has 190 members.

The section has scheduled seven meetings as follows:

November 4—Movie pointing out construction features of Aluminum Company of America all-aluminum building in Pittsburgh, Pa.

December 2—Jerome M. Bialosky,

Koppers Company, Inc., will talk on Corrosion Problems in the Chemical Industry.

January 6—J. Teres, Air Research and Development Command, will speak on Corrosion Problems in Military Aircraft.

February 3—John L. McPherson, Blaw-Knox Co., will discuss organization, duties and operation of materials department of design, engineering and construction company.

March 3—J. G. Christ, Westinghouse Electric Co., will talk on Metallurgical Aspects of Corrosion in Atomic Power Applications.

April 7—William J. Ruano, Attorney-at-Law, will speak on Highlights on Patents and Trade-Marks.

May 5—L. W. Gleekman, Wyandotte Chemicals Corp., will talk on A Materials Engineer in the Chemical Industry.

SHORT COURSE CALENDAR

1954

Nov. 15-17, UCLA, Los Angeles, California; Protective Coatings.

November, University of British Columbia, Vancouver, British Columbia, Canada.

1955

Jan. or Feb., UCLA, Los Angeles, Cal.

Feb. 2-4—University of Toronto, Hart House Theater, Toronto.

Feb. 16-18—Tulsa Section, Sixth Annual Short Course, Mayo Hotel, Tulsa, Okla.

Mar. 1-4, University of Tennessee, Knoxville.

Fall—Washington University, St. Louis, Missouri.



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Problems of Independent Operators Discussed at North Texas Meeting

H. D. Murray, production superintendent, The Hanley Company, spoke to 41 members and guests of North Texas Section NACE at a dinner meeting held in Dallas October 4. Mr. Murray discussed problems encountered by independent operators and explained that these were no different from those faced by larger operators but had to be recognized and controlled by fewer people. He stressed importance for those entering the field of independent operation to explore in advance all probabilities

which may be encountered rather than waiting until problems arise before attempting a solution.

Cone bottom lease tanks, Mr. Murray said, have a low corrosion rate and have made it possible for his company to operate for two years without the necessity of manually cleaning one tank. A circulating pump and the necessary lines make it possible to operate each tank with a minimum amount of waste drawn off to the burning pit and a maximum amount run to the pipe line as saleable material.

Meetings scheduled by North Texas Section are as follows:

November 1—K. D. Wahlquist, Southern Union Gas Company, will talk on pipe lines.

December 6—Fred K. Wood, Continental Oil Company, will speak on petroleum metallurgy.

January 3—Installation of officers.

February 7—Tentative speaker is Merrill Scheil, A. O. Smith Corp.

March 7—H. L. Bilhartz, Production Profits, Inc., chairman of South Central Region NACE will speak on secondary recovery.

May 2—Annual picnic.

Epoxies Are Discussed At New York Meeting

Approximately 95 members and guests attended the Metropolitan New York Section's September 22 meeting at the Chemists' Club in Manhattan. John Gehant of Devco & Reynolds Company, Inc. spoke on the "Use of Epoxy Coatings in Industrial Maintenance." Mr. Gehant, one of the pioneers in the development of epoxy resins, discussed the various types of epoxy coatings and their applications with special emphasis on their corrosion resistance. Mr. Gehant pointed out that epoxies have a great potential and show promise of replacing more conventional coatings for many exposure conditions.

The next regularly scheduled meeting of the section is for October 27 at the Chemists' Club with M. C. Miller of Ebasco Services, Inc. scheduled to speak on "Instruments for the Measurement of Corrosion."

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NACE MEETINGS CALENDAR

Nov.

- 8 Permian Basin Section. Panel discussion on refinery corrosion.
- 16 Montreal Section.
- 17 San Francisco Bay Area Section. D. C. Erdman, Electro Circuits, Inc., will talk on ultrasonic testing.

Dec.

- 8 Metropolitan New York Section. The Chemists' Club.
- 13 Permian Basin Section. Jack Williams, National Tank Co., Odessa, will discuss tank corrosion.
- 15 Greater Boston Section. Hotel Beaconsfield, Brookline, Mass.
- 21 Montreal Section. Corrosion testing.

Other Events

Nov.

- 4-5 Southeast Region Fall Meeting. Jacksonville, Fla.
- 15-19 UCLA Short Course and Western Region Meeting, Los Angeles, Cal.

Articles on corrosion control matters may be submitted for publication in CORROSION without invitation.

Abstracts published in the NACE Abstract Punch Card Service come from more than 500 periodicals all over the world. Coding by topic, journal, author and year is provided.



G. H. BENDIX, Director of Physical and Chemical Research, Continental Can Company is shown addressing members of Chicago Section's September 21 meeting on the topic "Corrosion Resistance of Tinplate."

Tinplate Corrosion Is Discussed at Chicago

Chicago Section NACE held its first 1954 meeting in Chicago September 21. G. H. Bendix, Director of Physical and Chemical Research, Continental Can Company, spoke on Corrosion Resistance of Tin Plate. Eighty-one members and their wives attended this ladies' night meeting at which Dr. Bendix described current manufacturing practices in tinplate and metal container industries and summarized electrochemical properties of tin, iron and tinplate with reference to differences in behavior depending upon presence or absence of oxygen. In addition to Dr. Bendix's talk, L. W. Ewing, General Conference Chairman for the 1955 NACE Conference, gave a brief talk on Oil Progress Week.

Meetings scheduled by Chicago Section are as follows:

October 19—J. E. Draley, Argonne National Laboratory, will discuss Corrosion Problems and Developments in the Field of Atomic Energy.

November 16—L. P. Sudrabin, Electro Rust-Proofing Corp., will speak on Criteria Used in Cathodic Protection.

January 18—H. V. Nyland, Sinclair Research Laboratories, will present the Applications of Economic Analysis to Refining Corrosion Problems.

February 15—J. S. Long, Devoe and Reynolds Co., Inc., will talk on the general subject of paints and painting.

April 19—Two movies, "Must It Rust" by Hot Dip Galvanizers Assn. and "The Big Crossing" on pipe line crossing of Straits of Mackinac are scheduled.

May 17—Annual Corrosion Round Table.

Students come from many states to attend short courses on corrosion usually held each fall by NACE's Tulsa and Shreveport Sections.

Furfural Production by New Process Is Reported by Armour

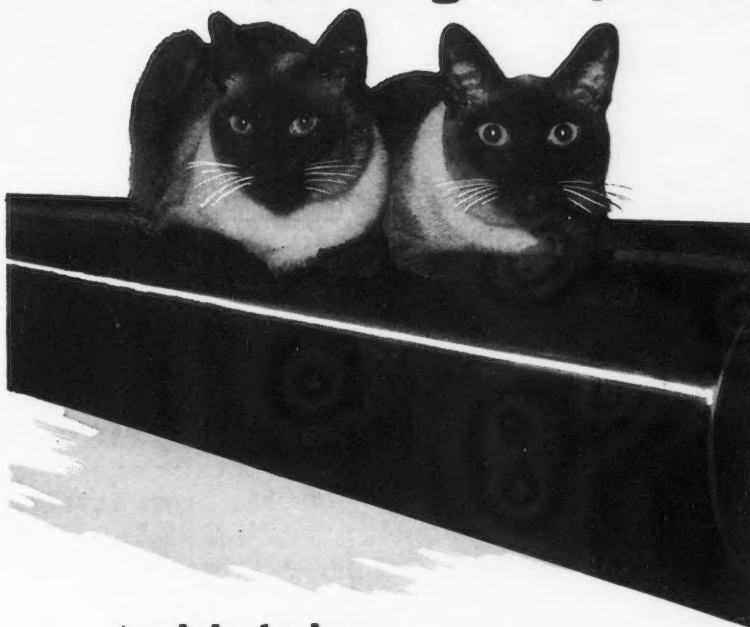
A new process for producing furfural alcohol intermediate resins by heating alcohol in presence of activated alumina is discussed in an article on Furfural Alcohol Plastics by Erik R. Nielson, a senior scientist of Armour Research Institute in Frontier, September, 1954 issue, a foundation periodical. Mr. Nielson says the process causes intermolecular dehydration to perform quickly and smoothly and eliminates steps required in the conventional method because catalyst is screened out.

The author explains that new process

intermediates are cheaper to produce than conventional type and are superior because of wide range of viscosities with good storage stability. He relates that the residual monomer can be kept at minimum and may replace present methods even where it is used most extensively in such fields as corrosion or chemically resistant cements and coatings. Mr. Nielson suggests plastic pipe as important outlet for the resin since it would be able to withstand higher temperatures and pressures than those made from such materials as thermoplastics. He states that the resin may be crosslinked to desired degree for producing solid resin to make instrument panels, plugs and electric insulators and feels this is sufficient ground to produce molding powder still sufficiently reactive to be compression-molded.

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150 Attend Dallas Plastic Materials Session

Results of Survey Are Discussed at Meeting of T-5D

Forty-three companies out of 60 replied to questionnaires submitted to manufacturers of plastic materials by Unit Committee T-5D on Plastic Materials of Construction. The answers were presented during the October 13 meeting of the committee held as part of October 12-15 meeting of South Central Region at the Adolphus Hotel in Dallas. One hundred and fifty members and guests attended the committee meeting.

Following are results of Survey No. 1 by T-5D:

Results of Survey No. 1 by NACE T-5D
October 12, 1954

While undoubtedly additional information will be received, the fact that 43 answers have already been returned from a total of 60 questionnaires, is gratifying and indicative of the tremendous interest in the objectives of NACE Committee T-5D.

The tabulated results of the survey given in Table 1 show that many different plastic structures are being used and that present acceptance is dependent to some extent upon the length of time that each plastic has been available and promotional activities of manufacturers of plastic materials.

It will be noted that over 40 percent of those replying were familiar with at least eight plastics which are being used to considerable extent in the form of pipe, ducts and vessels. There were some failures reported, of course, but even in some instances where failure occurred, the plastic materials of construction were superior to any other known product. For example, a glass reinforced impeller fan operating at 100 degrees F with sulfur dioxide fumes failed in 18 months. It had replaced a Type 304 stainless steel impeller and Type 317 stainless steel impeller which each lasted approximately three months. Likewise, a glass reinforced polyester chlorine dioxide bleaching tower top operating at 160 degrees F failed after six months, presumably due to inadequate physical properties and insufficient chemical resistance. It had replaced a stainless steel top which lasted approximately two months.

It is hoped that through the efforts of task groups to be appointed that more complete data will be secured during the next six months. It is also hoped that suppliers of plastic materials of construction will continue to supply much needed chemical and physical data.

An attempt has been made herein to correlate the results of the corrosion section of the survey showing both the generic nature of the plastic and the

TABLE 1—Tabulation of 43 Answers Received Prior to October 12, 1954

TYPE PLASTIC	1st Hand Knowledge	Pipe	Ducts	Valves	Vessels	Miscellaneous*
A. Saran.....	22	20	2	5	0	0
B. Phenolic Resin, Asbestos-Filled.....	18	14	5	1	4	1
C. Phenolic Resin, Carbon-Filled.....	7	5	1	1	0	..
D. Furan Resin, Asbestos-Filled.....	10	6	6	1	0	..
E. Furan Resin, Carbon-Filled.....	10	7	3	2	1	..
F. PVC 1.....	20	14	12	0	0	..
G. PVC 2.....	7	6	2	0	0	..
H. Polyethylene.....	21	17	3	3	0	..
I. Styrene Rubber Blends.....	19	15	3	1	0	..
J. Glass Reinforced Polyesters.....	20	7	7	1	1	2
K. Acrylic Resin.....	7	2	0	0	1	..
L. Epoxy Resin.....	5	2	3	0	1	..
M. Fluorinated Ethylene Resins.....	17	5	3	9	2	..
N. Cellulose Esters.....	2	2	0	0	0	..
O. Nylon.....	3	1	0	0	0	..
P. Polyvinyl Alcohol.....	1	0	0	0	1	..
Q. Impervious Graphite.....	15	10	3	3	3	2

* Roofs, fans, pumps, valves, stacks and other equipment.

TABLE 2
Experience on Plastic Structures Reported in Answer to Survey by T-5D
(Data Supplied on Laboratory or Plant Testing Panels Are Not Included)

TYPE PLASTIC	Corrosive Environment	Concentration (%)	Maximum Temp. (°F.)	Time (Mo.)	Success	Failure
A. Saran.....	HCl	35	80	95	X	
			270	60	X	
		35	120		X	
		35	150		X	
		35	100		X	
		32	180		X	
B. & C. Phenolic Resin, Asbestos-Filled... Phenolic Resin, Carbon-Filled...	HCl	35	150		X	X-B
		32	180			X
		35	200	60		
		30	100		X	
D. & E. Furan Resin, Asbestos-Filled..... Furan Resin, Carbon-Filled.....	HCl	35	140		X	
		35	100		X	
		35	150		X	
F. & G. PVC 1..... PVC 2.....	HCl	35	100	6	X	
		35	140		X	
		15	135	22	X	
		35	200	36		X-Pipe Sagged
		35	150		X	
H. Polyethylene.....	HCl	15	90	48	X	
		15	135	22	X	
I. Styrene Rubber Blends.....	HCl	35	100	2	X	
			140		X	
J. Glass Reinforced Polyesters.....	HCl	35	140		X	
		20	100	4	X	
Q. Impervious Graphite.....	HCl	35	60			X
			180		X	
			140		X	
			100		X	
A. Saran.....	Chlorine	Wet	100	3		X
		Wet			X	
		Wet			X	
B. & C. Phenolic Resin, Asbestos-Filled... Phenolic Resin, Carbon-Filled...	Chlorine	Wet	190	10		X
		Wet	170		X	
		Wet	176		X	
		Wet	190	120	X	
		Wet	190	18	X	
		Wet	150		X-B	X-C
D. & E. Furan Resin, Asbestos-Filled..... Furan Resin, Carbon-Filled.....	Chlorine	Wet	170		X	
		Wet	175		X	
		Wet	190	24		X
F. & G. PVC 1..... PVC 2.....	Chlorine	Wet	105	3		X
H. Polyethylene.....	Chlorine	Wet	100	3	X	
I. Styrene Rubber Blends.....	Chlorine	Wet	195	2	X	
		Wet	100	3	X	
		Wet	100	24	X	
		Wet	90	48	X	
		Wet	150		X	
		Wet	100	3	X	
		Wet	80	12	X	
		Wet	100	6	X	
J. Glass Reinforced Polyesters.....	Chlorine	Wet			X	

(Continued on Page 10)



**"PUTTING
Permanence
IN PIPE"**

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★ HOT DOPE Straight from the Kettle on PIPE PROTECTION

★
By Boyd Mayes

Recently saw about the most interesting map of the Gulf Coast that I reckon anybody would care to see. While it didn't highlight the towns and vacation spots—it was lit up like the old fashioned Christmas tree with red lines and dollar marks. Every red line was an important deal to all of us—because every line on that map represented the pipe lines running in every direction from Texas and Louisiana . . . and represented literally barrels of dough! Yes, sir, pipelining is really big business, and it sure gave us a feeling of pride to know that it had been our privilege to have contributed to the building of many of those main lines through our work and equipment. Which reminds me of what 'ole Zeke used to say, "...if a man ain't proud of his work—he ain't much fitten for it!"

We think the boys who did all that pipeline laying and stringing shown on that map are sure entitled to be proud...for they have helped make history. To meet their requirements we keep the best in men and equipment for coating and wrapping pipe; we've been "putting permanence in pipe" for over a quarter of a century.

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TABLE 2—Continued

TYPE PLASTIC	Corrosive Environment	Concentration (%)	Maximum Temp. (°F.)	Time (Mo.)	Success	Failure
A. Saran.....	Chlorine	Dry	100	24		X
F. & G.		Dry	120	9		X
PVC 1.....	Chlorine	Dry	170		X	
PVC 2.....					X	
H. Polyethylene.....	Chlorine	Dry	100	24	X	
I. Styrene Rubber Blends.....	Chlorine	Dry	100	24	X	
		Dry	120	12	X	
		Dry	100	8	X	
		Dry	80	3	X	
A. Saran.....	ClO ₂		68	12	X	
J. Glass Reinforced Polyesters.....	Cl ₂ , ClO ₂		160	6		X
F. & G.					X	
PVC 1.....	SbCl ₃ , HCl, Cl ₂		130	12	X	
PVC 2.....	Chlorine and HCl	13	50	19	X	
	NaOCl	13	110	36	X	
		13	50	36	X-G	
H. Polyethylene.....	NaOCl	13	80		X	
						X
A. Saran.....	H ₂ SO ₄	74	100	2	X	
		72	100		X	
B. & C.					X	
Phenolic Resin, Asbestos-Filled.....	H ₂ SO ₄	15	180		X	
Phenolic Resin, Carbon-Filled.....		30	140	36	X	
		10	200		X	
		50	230	60	X	
D. & E.					X	
Furan Resin, Asbestos-Filled.....	H ₂ SO ₄	30	140	36	X	
Furan Resin, Carbon-Filled.....		10	212		X	
			268	2	X	
F. & G.						
PVC 1.....	H ₂ SO ₄	96	3		X	
PVC 2.....		30	140	36	X	
		45		24	X	
				36	X	
				36	X	
		10	100		X	
			100	18	X	
H. Polyethylene.....	H ₂ SO ₄	45	140	22	X	
I. Styrene Rubber Blends.....	H ₂ SO ₄		100	1	X	
			210	2	X*	
		10	75		X	
J. Glass Reinforced Polyesters.....	H ₂ SO ₄	2	220	3		X
		30	85	5	X	
A. Saran.....	HNO ₃	5	100			X†
F. & G.						
PVC 1.....	H ₂ SO ₄ (12), HNO ₃ (10), NISO ₄ (15)		180	4	X	
PVC 2.....	HNO ₃	5	24		X	
H. Polyethylene.....	HNO ₃ , HF		100	19	X	
A. Saran.....	Al ₂ (SO ₄) ₃ , H ₂ SO ₄	10	100	6	X	
B. & C.					X	
Phenolic Resin, Asbestos-Filled.....	FeCl ₃		120		X	
Phenolic Resin, Carbon-Filled.....					X	
D. & E.					X	
Furan Resin, Asbestos-Filled.....	NH ₄ Cl		175		X	
F. & G.					X	
PVC 1.....	FeCl ₃		120		X	
PVC 2.....	Al ₂ (SO ₄) ₃	20	110	6	X	
		10	100		X	
H. Polyethylene.....	Cr ₂ (SO ₄) ₃		100	4	X	
I. Styrene Rubber Blends.....	Al ₂ (SO ₄) ₃		100	2	X	
	(NH ₄) ₂ SO ₄		130	12	X	
J. Glass Reinforced Polyesters.....	Cr ₂ (SO ₄) ₃	4	160	8	X	
Q. Impervious Graphite.....	CaCl ₂		175		X	
B. & C.					X-C	
Phenolic Resin, Asbestos-Filled.....	HF				X	
Phenolic Resin, Carbon-Filled.....					X	
D. & E.					X	
Furan Resin, Asbestos-Filled.....	Acetic Acid		135	24	X	
H. Polyethylene.....	Sodium Hydroxide	8	170	3	X	
I. Styrene Rubber Blends.....	NaCl, NH ₃		60	3	X	
	NaCl		12		X	
J. Glass Reinforced Polyesters.....	NaOH	10	85	3	X	
	Cr ₂ O ₃		160	8	X	
	Acetic Acid				X	
	NH ₃				X	
Q. Impervious Graphite.....	H ₃ PO ₄	70	175	9		X
F. & G.					X	
PVC 1.....	Bright Nickel Plating		140	6	X	
PVC 2.....	NO ₂ Gas		65		X	
	Chromate Plating		140	21	X	
	Crude Oil & Salt		120	1	X	
	Sour Crude		140	40	X	
H. Polyethylene.....	Crude Oil & Salt		100		X	
	Benzyl Chloride				X	
	Plating Tank				X	
J. Glass Reinforced Polyesters.....	HCl, Cl ₂ , Organic SO ₂		140	8	X	
Q. Impervious Graphite.....	Benzal Chloride-HCl		280	18	X	
	Benzene, Benzene Hexachloride-Cl ₂			14	X	
	Chloroacetic Acid-HCl			9	X	
				3	X	

* Fumes only.

† Embrittled.

Prefabricated Plastic Pipe Line Film Unit Committee Organized

Formation of a Unit Committee on Prefabricated Plastic Film for Use on Pipe Lines was approved by Group Committee T-2 on Pipe Line Corrosion at an October 12 meeting which was part of the October 12-15 sessions of South Central Region at the Adolphus Hotel in Dallas. The committee is expected to work on minimum standards for formulation of film and application methods.

Responsibility for preparing minimum standards for protecting pipe lines to include coatings and cathodic protection was accepted by T-2.

Tanker Committee Will Investigate Economics

Economic aspects of corrosion in tanker compartments will be investigated first it was decided at an October 13 meeting of T-3H on Tanker Corrosion during the South Central Region at the Adolphus Hotel in Dallas. The tentative scope of investigation was approved during the committee meeting. It includes a definition of corrosion sustained, its cost and importance with respect to economic solution, analyses of causes and mechanisms and a study of preventive measures such as inhibitors, cathodic protection, protective coatings, materials of construction and design, operating procedures and atmospheric control.

Committee plans to study corrosion of tankers in clean and dirty service including those used for chemical and petroleum cargoes. Representatives of several companies operating tankers have offered to present pertinent laboratory and field data during the National Association of Corrosion Engineers Eleventh Annual Conference and Exposition to be held in Chicago on March 7-11.

Screening Procedure on Inhibitors Is Sought

Establishment of a task group to prepare a procedure for screening inhibitors for use in pipe lines and tanks in sour crude service was agreed on at an October 12 meeting of Unit Committee T-2F on Internal Sour Crude Corrosion of Pipe Lines and Tanks held during the meeting of South Central Region at the Adolphus Hotel in Dallas.

Results of Survey —

(Continued From Page 9)

corrosive involved. Unfortunately, it was not possible to differentiate between carbon and asbestos-filled phenolic or furan structures nor between Types I and II PVC.

While much of the tabulated information is incomplete, it will serve as a foundation for more complete surveys in the future. In any case, the data indicates that the objectives of T-5D are sound and that plastic structures are performing satisfactorily in chemical industry.

Shock to Address Sabine-Neches Section At November 11 Meeting

Dorsey Shock, Continental Oil Company, Ponca City, Okla., will talk on iron analysis at the November 11 meeting of Sabine-Neches Section. This meeting is one of four arranged by the section. S. J. Gaido, Pipe Line Service Co., Houston, was the scheduled speaker at the October 28 meeting.

Other meetings scheduled were:

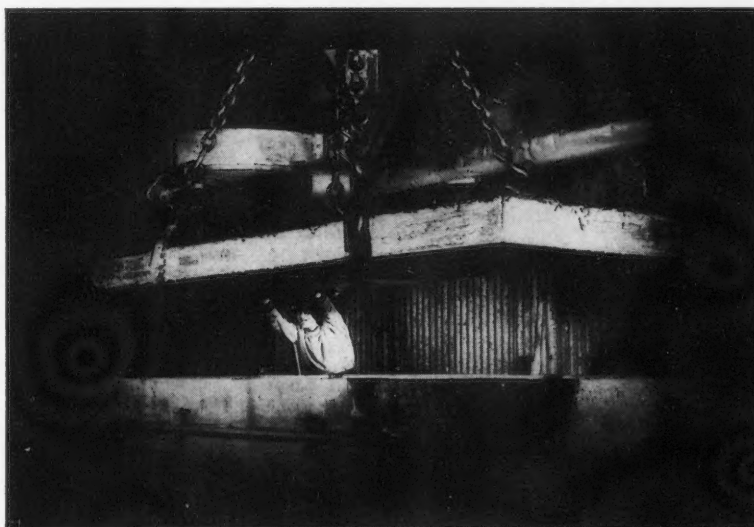
December 16—E. C. Greco, United Gas Corp., Shreveport, will speak on corrosion problems in oil and gas production equipment.

January 26—Ladies night and installation of officers.

New Titanium Alloy Developed at Battelle

A new titanium alloy capable of being heat treated to very high strength has been developed at Battelle Institute, Columbus, Ohio. Paul D. Frost, research metallurgist at the institute reported on the development at the National Aircraft Standards Committee meeting in Cleveland October 12.

Mr. Frost and his associates said they believed the heat treating system developed for the new alloy can be applied successfully to all new commercial titanium alloys. The new material contains 3% manganese, 1% each of iron, chromium, vanadium and molybdenum, with the balance titanium.



Subject: lead sheet and pipe

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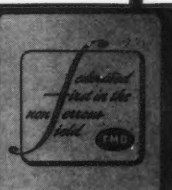
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SCENES AT DALLAS Technical Committee meetings: Top, seated center, L. L. Sline, Sline Industrial Painters, Houston, chairman presides at a session of T-6B; Second, left, W. H. Stewart, Sun Pipe Line Co., Beaumont, chairman of T-2 and, right, John C. Watts, Jr., Humble Pipe Line Co., Midland, Texas confer during a meeting of T-2F of which Mr. Watts is chairman; Third, left, Jack L. Battle, Humble Oil and Ref. Co., Houston, chairman and W. C. Koger, Cities Service Oil Company, Bartlesville, Okla., vice-chairman photographed during a session of T-1H; Bottom, left, W. C. Stewart and L. P. Sudrabin, Electro Rust-Proofing Corp., Belleville, N. J. chairman of T-2C talk at a meeting of T-2C.



Protective Coatings Chart Is Discussed by T-6B

The revised chart on protective coatings for resistance to atmospheric corrosion was discussed during the October 13 meeting of Unit Committee T-6B on Protective Coatings for Resistance to

Atmospheric Corrosion held as part of October 12-15 meeting of South Central Region at the Adolphus Hotel in Dallas. The chart will be completed in time for the National Association of Corrosion Engineers 11th Annual Conference and Exposition to be held in Chicago on March 7-11 and will be published shortly thereafter. Twenty members and guests attended the committee meeting.

Oil Well Casing Cathodic Protection Held Practical

The practical value of cathodic protection to mitigate oil well casing corrosion was recognized by Unit Committee T-1H on Oil String Casing Corrosion at a meeting held October 12 as part of the October 12-15 meeting of South Central Region at the Adolphus Hotel in Dallas. Seventy-five members and guests heard several companies report using this type protection in the field and some members expressed the opinion that it will be an economical method of mitigating casing corrosion.

Minimum Standards for Coal Tar Coatings Sought

Preparation of minimum standards for coal tar coatings to cover materials, application, surface preparation and handling was decided during October 12 meeting of Unit Committee T-2G on Coal Tar Coatings for Underground Use. A tentative draft was agreed on

and task groups formed to complete the standards during the committee meeting which was part of the October 12-15 meeting of South Central Region held at the Adolphus Hotel in Dallas.

Leakage Conductance Report Is Approved

A proposed standard for measuring leakage conductance in buried pipe lines was approved during an October 13 meeting of Unit Committee T-2D on Standardization of Procedures for Measuring Pipe Coating Leakage Conductance. Fifteen members and guests attended the meeting during the October South Central Region meeting at the Adolphus Hotel in Dallas. The proposal was submitted to Group Committee T-2 on Pipe Line Corrosion and is expected to be published in the near future.

Report on Screening of Inhibitors Completed

A standard laboratory procedure for screening corrosion inhibitors for use in oil and gas wells was approved by Unit Committee T-1K on Inhibitors for Oil and Gas Wells October 12. The committee met during the October 12-15 meeting of South Central Region at the Adolphus Hotel in Dallas. The procedure will be submitted to Group Committee T-1 on Corrosion in Oil and Gas Well Equipment for approval and is expected to be published in the near future.

Book on Oil and Gas Well Corrosion Reviewed

Outline of a book on corrosion of oil and gas well equipment being prepared by Group Committee T-1 on Corrosion in Oil and Gas Well Equipment was presented during the October 13 meeting of the committee by John D. Sudbury, Continental Oil Co., Ponca City, Oklahoma, who is chairman of T-1 editorial committee for the book.

Approximately 175 members and guests attended the meeting during the October 12-15 meeting of South Central Region held at the Adolphus Hotel in Dallas. The outline was discussed and members were asked to send in written suggestions, pictures and illustrations for the book which is scheduled for completion in July 1955. Reports from T-1 Unit Committees represented in Dallas were made during the committee meeting.

Plastic Materials Papers Presented Before 100

Six technical papers on performance of plastic materials were presented before 100 members and guests attending the October 12 meeting of Unit Committee T-1J on Oil Field Structural Plastics which was part of the October 12-15 meeting of South Central Region at the Adolphus Hotel in Dallas. Plans are to publish abstracts of the papers in Technical Committee News Section of December issue of CORROSION.

The committee is continuing to gather data on long term testing of plastic pipe used in oil and gas well production.

Second Interim Report On Lead Sheathed Cables Soon to Be Published

The second interim report of Technical Unit Committee T-4B has been completed and is scheduled for publication in the December issue of CORROSION. The report entitled, "Tests and Surveys for Lead Sheathed Cables in the Utilities Industry," was compiled by Task Group T-4B-3 on Tests and Surveys. Task Group T-4B-3 began work on the interim report in 1952 under the old designation, Technical Practices Committee 16D and much of the work was done by F. E. Kulman, Consolidated Edison Company of N. Y., Inc. New York, who then was chairman of TP-16D. The work was continued under the leadership of J. C. Howell, Public Service Electric & Gas Company, Maplewood, New Jersey, current chairman of T-4B-3. Mr. Kulman is now chairman of Group Committee T-4.

The interim report is in three parts. The first part is a glossary of electrolysis terms, which was prepared by the committee to facilitate reading and understanding the report. The second part is an abstract to the questionnaire on tests and surveys, which was prepared by J. C. Howell. The third part is a summary of replies to the questionnaire on tests and surveys.

The report covers the test and survey practices of 22 utility companies and electrolysis committees concerned with lead sheath cables. These include electric utilities, telephone and telegraph companies and a railroad. The scope of the study includes present practices with respect to tests on lead sheath cables in underground ducts and buried in the earth.

General subjects covered in the report are types of surveys, instruments and equipment used, chemical corrosion encountered, interpretation of test data and general miscellaneous questions.

The interim report is the second of a series of four being prepared by task groups of Unit Committee T-4B on Corrosion of Cable Sheaths. This report on tests and surveys contains much useful information the field of corrosion mitigation in the utilities industry.

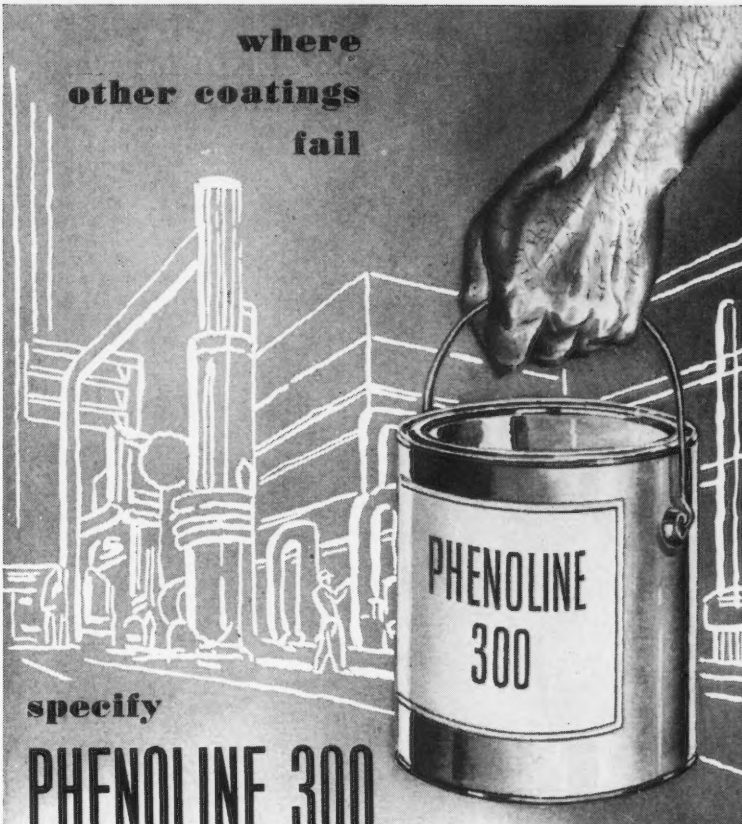
Cathodic Protection Is Discussed by T-1A

Cathodic protection was discussed at the September 15 meeting of Unit Committee T-1A in Santa Fe Springs, California.

The committee discussed the use of impressed current and sacrificial anodes to cathodically protect wash tanks against internal corrosion. Protection of pipe and casing against external corrosion was also discussed. All attending the meeting participated in a round table discussion of field results of his company's current cathodic protection practices.

Unit Committee T-1A, studying corrosion of oil and gas well equipment in the Los Angeles area, holds monthly meetings at which various aspects for oil and gas well equipment corrosion are discussed. The committee has been very active over the past few years and has contributed considerably to the efforts of the parent committee T-1.

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Building Ground Beds to Match Standard Rectifiers Recommended at T-2B Meeting

During a meeting of Unit Committee T-2B on Anodes for Impressed Currents, one of the members said that his company favors use of standard size rectifiers and of building ground beds to match the rectifier output, thus making it unnecessary to order units of various ratings and specifications. His company's operations have been of such magnitude that sufficient data on past installations are available to permit determination of the number of anodes required for any particular ground bed from experience once the soil resistivity at ground bed site has been determined.

He said his standard ground bed involves placing graphite anodes in coke breeze backfill in 12-inch diameter holes

spaced 25 feet apart and drilled to 12-foot depth, with depths up to 20 feet at some locations. He explained that in his operations, the most important phase of designing a ground bed lies in proper measurement of soil resistivity at a proposed ground bed site. Once this resistivity has been properly determined, experience indicates the proper number of anodes to use. He said that in many instances split ground beds are used with a single rectifier. This involves using half the ground bed on one side of the pipe line not closer than 100 feet to the line, with the other half of the ground bed on the other side of the pipeline, at least 100 feet from the line. The result is roughly the same as two separate

ground beds operating in parallel which, where the soil conditions are approximately the same at both sides result in lower over-all ground bed resistance to soil than would be obtained if all the anodes were installed in a single ground bed.

Another member of the committee indicated that in his opinion ground bed resistance should be taken as the resistance of the ground bed alone and should not include the resistance of cables from the ground bed to the rectifier or from the rectifier to the pipe line, or the resistance between the pipe line and soil. He believes that by confining the determination of the resistance to the ground bed proper the problem is confined to the determination of average soil resistivity at a proposed ground bed site and design of the ground bed for a desired value of resistance in that particular soil.

Failure of Anode Leads

Mention was made of one instance of graphite anode failure caused by anode leads pulling away from the graphite anodes. In discussing the reported failure, it was indicated the trouble may have arisen from manufacturing defects connected with soldering of the anode leads into the brass ferrule which is driven into the end of the graphite anode. A member said the manufacturer has recently improved manufacturing techniques and that all anodes now issued from the factory are subjected to a pull test and that in the future it is not contemplated there will be further instances of field complaints of poor lead connections.

A member of the committee offered a suggestion for the use of graphite anodes in instances where backfill cannot be used conveniently with the anodes, as often is the case in very wet or marshy locations. He said that in order to avoid concentration of current discharge at the lead end of the anodes they might be installed end to end as one unit horizontally with the lead ends together. The effect of such an arrangement is that of a single long anode having the lead connection in the middle so that with current discharge concentrated at the extreme ends rather than at lead ends there will thus be less tendency for early failure of the anode connections. In answer to a question concerning the effect on current discharge of impregnation at the lead end of a graphite anode, the member indicated there is no effect from this impregnation other than reduction in the rate of oxidation of the anode.

Vertical vs Horizontal Installation

Another subject discussed was the relative effectiveness of vertically installed anodes compared to horizontally installed anodes. Most felt that wherever possible anodes should be installed vertically because in most cases, a vertical anode will be more efficient in reducing ground bed resistance than one installed horizontally. It was mentioned that in some instances standard length anodes have been cut off in order to install them vertically at sites where surface soil above rock is shallow.

The importance of using low resistivity coke breeze backfill was discussed. One member mentioned applications where graphite anodes are installed in coke

(Continued on Page 16)



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DO YOU KNOW HOW MUCH CORROSION COSTS PRODUCERS EACH YEAR?



CORROSION PREVENTIVES

In a survey conducted by the National Association of Corrosion Engineers, covering 537 "sweet" oil wells and 3,052 "sour" oil wells, 30% of the "sweet" wells and 80% of the "sour" showed evidence of corrosion attack. A survey conducted by the Natural Gasoline Association of America showed that out of 2,466 scattered gas and gas condensate wells surveyed, 46% showed corrosion damage and metal losses. It has been estimated that the overall cost of corrosion on producing oil properties in the United States runs as high as \$500.00 per well . . . a total of approximately \$250,000,000.00 annually. Corrosion cost in gas and gas-condensate wells has been estimated at approximately \$4.30 per MMCF of gas produced, or an annual total of \$13,000,000.00. The total cost of corrosion in all these wells is \$263,000,000.00!

While such figures certainly reflect the tremendous cost of corrosion to producers in general, they may not show what the losses due to corrosion are on your properties. Why not ask your Kontol engineer for a corrosion survey? There is no obligation, and he can show you how Kontol inhibitors help you stop these profit-cutting corrosion losses.

For complete information call your Tretolite man.

TRETOLITE COMPANY

A Division of Petrolite Corporation

369 Marshall Avenue, Saint Louis 19, Missouri
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Prevent corrosion of carbon steel and alloys

Stop hydrogen embrittlement and blistering

Are easy to apply. Can be pumped, dumped, lubricated

Available also in solid stick form

Safe, easy to handle. No extraordinary precautions required

Do not complicate scaling or emulsification problems

Do not deposit formation-plugging precipitates

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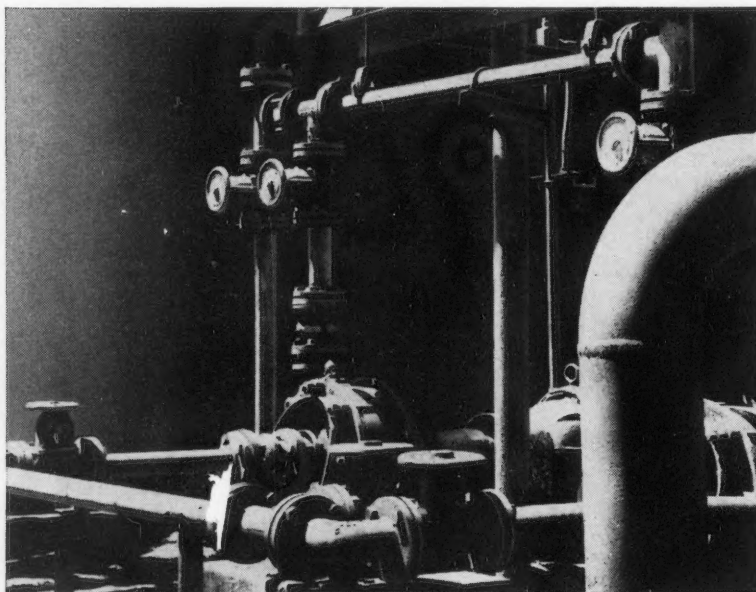
**DEMULSIFYING • DESALTING • WATER DE-OILING
CORROSION PREVENTING • SCALE PREVENTING
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HAVE ALL THE FACTS ON**

KONTOL

NO SHUTDOWNS FOR THIS INSTALLATION!

These corrosion-resistant Saran Lined Pipes, Fittings and Valves have conveyed hydrochloric acid for seven years . . . with trouble-free service!



This installation of a large chemical company has been intermittently conveying hydrochloric acid for seven years with no shutdowns because of corrosion. There has been no danger of injury from bursting pipes or sudden leaks either, for this steel-clad pipe has high-pressure strength and durability. And the joints have remained airtight and leakproof.

Installation was simple, also. Saran lined steel pipe is easily cut and threaded in the

field, without need of special tools. Because of its rigidity even long spans require a minimum of supports.

If your production requires handling of corrosive liquids, investigate saran lined pipe, fittings and valves. We'll be glad to assist you with installation plans.

RELATED SARAN PRODUCTS—Saran rubber tank lining • Saran rubber molding stock • Saran tubing and fittings • Saran pipe and fittings.

Saran Lined Pipe Company
2415 Burdette Ave. • Ferndale 20, Mich.



Please send me a copy of your catalog on Saran Lined Pipe, Valves and Fittings.

Name _____
Title _____
Company _____
Address _____
City _____ State _____

SP 1169D

you can depend on **DOW PLASTICS**

Dow

T-3A Submits List Of Corrosion Inhibitors For Early Publication

A list of corrosion inhibitors compiled by Unit Committee T-3A on Corrosion Inhibitors has been submitted for publication according to the committee chairman, R. S. Wise, National Aluminum Corporation, Chicago, Illinois. T-3A (old designation TP-9) has been working on the list since May, 1951. It is an alphabetical list of corrosion inhibitors collecting for ready use necessary pertinent information on the mechanism and uses of important inhibitors. It is designed for the corrosion engineer who has a limited knowledge of inhibitors rather than for the advanced researcher interested in minor differences.

Because relatively few materials fail to act as an inhibitor under some exceptional condition, an attempt was made to list only those materials whose use has attained commercial significance. Each material listed is accompanied by a literature reference to guide the reader to details on the method of application, limits of utility and other pertinent facts. Wherever possible, the references are chosen to provide by cross references a thorough introduction to related materials, their method of action and extent of usefulness as well as to characteristics of the subject inhibitor.

Additional information includes names of suppliers, metals which can be protected, preferred environment with respect to pH and temperature range and dosage which has been used successfully.

The list of corrosion inhibitors may be published soon.

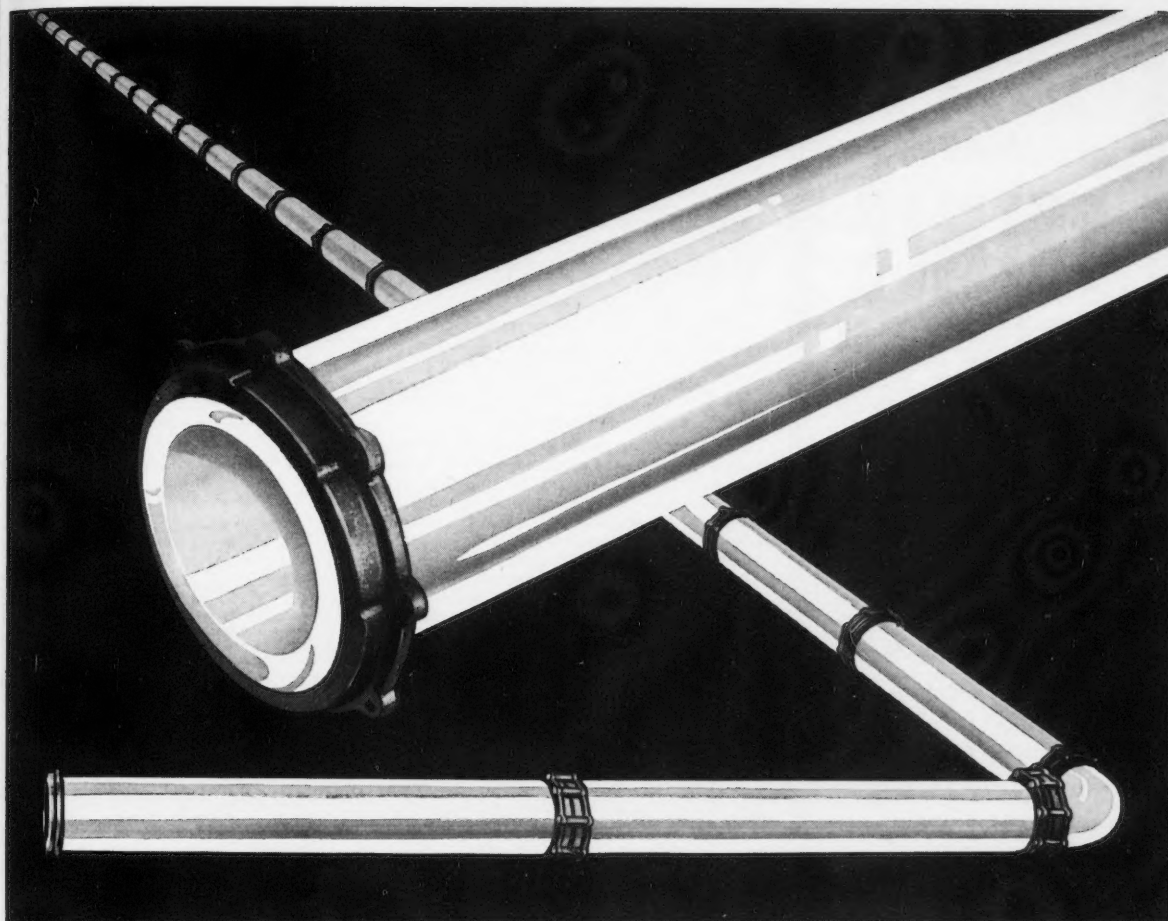
Building Ground Beds —

(Continued From Page 14)

breeze columns in deep holes depending upon the coke breeze column, which often extends several feet below the anode, to serve as an effective electrode in reducing the anode resistance to ground. Another member indicated that the carbonaceous backfill BF3 when subjected to pressures up to about six pounds per square foot in a testing container will have indicated resistance in order of 2 or 3 ohm centimeters dry and about one ohm centimeter less than these values if wet. Coke breeze backfill obtained from various sources may have marked variations in resistivity but if obtained from a satisfactory source, should be at least within the 20 to 30 ohm centimeter range and preferably less. It was noted that in purchasing coke breeze for ground bed purposes, resistivity of the material should be checked to assure that unusually high resistivity material is not obtained. If the resistivity is too high, the result will be much higher ground bed resistances than designed figures might indicate. It also was noted that petroleum coke breeze normally will be of high resistivity unless it has been heat treated to reduce resistivity.

Extra copies of CORROSION can be bought from NACE, 1061 M & M Bldg., Houston.

Members may get the distinctive NACE membership pin for \$10.



For some applications **ONLY CHEMICAL CERAMICS** *will do*

For only chemical ceramics will resist all acids, alkalis and all solvents (with the exceptions of fluorides and hot caustics). White chemical porcelain, in particular, offers important processing advantages. In addition to its chemical inertness, white chemical porcelain is completely non-toxic and non-contaminating. Its smooth glazed surface makes cleaning a matter of minutes. It can be fabricated in one-piece construction into vessels of practically any shape and in sizes from a thimble to a thousand gallon tank. Many items of equipment, such as pipe, valves, fittings, sinks, filters and storage vessels are standard items carried in stock and ready for immediate shipment. Other items can be fabricated on short notice.

The United States Stoneware Company has been one of the world's principal producers of chemical ceramics for more than ninety years. Continual research and im-

proved manufacturing techniques give today's chemical ceramics characteristics far superior to those of even a few years ago: better heat-shock resistance, higher mechanical strength, closer dimensional tolerances.

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Plastics and Synthetics Division

499-D

Other Corrosion-Resistant materials manufactured and fabricated by U. S. Stoneware and its affiliated companies, include: TYGON Plastics, Duralon Resins, natural and synthetic rubber products, lead-lined equipment, adhesives and organic bonding agents, acid-brick and cements, and sintered metallic oxides.

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chemistry...*

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From acid (rust)
condition to alkaline
(NON-RUST) condition
in one easy step with

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Backwards"



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Bar or Ball Coupons Eliminate Edge Effects, T-2C Told at Dallas

That the use of bar or ball coupons to test cathodic protection eliminates edge effects was revealed during the October 12 session of Unit Committee T-2C on Minimum Current Requirements for Cathodic Protection which was held during the October 12-13 meeting of South Central Region at the Adolphus Hotel in Dallas.

One member felt coupons placed at a distance from a pipe line will not give satisfactory results and questioned their value because surface factors existing on pipe lines will not be duplicated on coupons distant from the line.

Ready polarization of graphitic products of corrosion was reported by a member. So much interest was shown he was requested to report further on the matter during the National Association of Corrosion Engineers Eleventh Annual Conference and Exhibition to be held in Chicago on March 7-11. The committee plans to complete tentative recommendations for protection criteria at the March meeting.

Utilities' Corrosion Costs Is Topic for T-4F

The expense to a public utility as a result of consumer's corrosion problems will be the main topic of discussion at a Unit Committee T-4F meeting, scheduled to be held November 18 in Los Angeles, California.

Committee T-4F, studying materials selection for corrosion mitigation in the utilities industry is inviting engineers, architects, building inspectors, builders and plumbers to the meeting for the purpose of giving them information on corrosion control. Specific items to be discussed are:

1. Materials selection and practical ap-

plication and use to prevent corrosion of plumbing.

2. Improved specifications for cast iron soil pipe to reduce susceptibility to internal and external graphitic corrosion. This always has been a problem of water and sewage works operators. T-4F hopes to develop information helpful in finding practical and economical remedies.

3. Classification of corrosion factors so particular materials may be selected for corrosion resistance. This subject will concern specific factors in corrosive environments leading to special selection of materials and combinations of materials which may be placed in close proximity without undue corrosion.

How CORROSION Is Indexed

Annually, in December issue, a cross-referenced tabular topical index of the material published in the Technical Section is published. An alphabetical subject index will be published in the December, 1954 issue.

Annually, in December issue, an alphabetical author index is published.

Annually, in December, a tabular index to the Corrosion Abstract Section is published.

Monthly, technical articles published in Corrosion are abstracted in the Corrosion Abstract Punch Card Service.

5 Year Index, 1945-49, consisting of a cross-referenced tabular topical index and an alphabetical author index was published in the December, 1950 issue of Corrosion. Bibliographic Surveys of Corrosion—Corrosion Technical Material is indexed in the NACE's Bibliographic Surveys.

Corrosion is regularly indexed by Engineering Index.

10-year Index, 1945-54—In preparation and scheduled to appear early in 1955 is a 10-year index to the Technical Material published in Corrosion. It will consist of an alphabetical subject index and an alphabetical author index.

No indices of other sections of Corrosion are prepared by NACE.

All indexing is done, as far as practical, according to the NACE Abstract Filing System Index, which is used for NACE Abstract Punch Cards and the biennial Bibliographic Surveys of Corrosion.

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Corrosion control for under-ground and under-water pipelines and other metal structures regardless of all other methods used.

Anode folders or technical consultation with our engineers available upon request.

APEX SMELTING COMPANY

APEX Anodes are available in 17 lb. and 32 lb. bare anode with or without wire, or complete packaged anode with wire and back-fill ready for installation.



General News

Gordon N. Scott and W.H.J. Vernon Are Named To Receive 1955 Speller and Whitney Awards

American Nuclear Society Organized October 11

A meeting to organize the American Nuclear Society was held October 11 by 29 representatives of 13,000 scientists and engineers engaged full-time in governmental, industrial and educational aspects of atomic energy activity in the United States at the National Academy of Sciences in Washington, D. C.

Principal purpose of the society is to foster integration and advancement of nuclear science and technology through interchange of information and ideas in all fields of research utilizing nuclear techniques, it was reported.

In congratulating the society on its founding, Representative Sterling Cole, chairman, Joint Committee on Atomic Energy, said: "I deem it particularly fortunate that this new society is being founded so soon after the passage of the Atomic Energy Act of 1954 which seeks to encourage—both within our own country and with friendly nations abroad—the dissemination and exchange of unclassified scientific and technical information and thereby to promote scientific and industrial progress and public understanding."

In addition to the organizing committee 200 senior scientists and engineers have accepted invitations to become charter members, it was said. Membership is open only to individuals with degrees in physics, chemistry, mathematics, biology, medicine and all branches of engineering who are engaged in professional activity in one or more of the fields of nuclear science and engineering. It will not be limited to U. S. citizens and it is expected that cooperative conferences will be held with foreign technical groups, according to the report.

First technical conference of the society is scheduled at Pennsylvania State University, State College, Pa., on June 27-29, 1955, it was announced.

Krupp Periodical

Publication Is Resumed

Technesen Mitteilungen Krupp, a periodical of the Krupp works, Essen, Germany, is being published again. Numbers 1 and 2 were issued in January and number 3 in June. The address of the publication is: Werksbucherei Krupp, Postfach 739, Essen.

The first three issues, carefully printed with the precision common to German technical literature, contain fully illustrated articles with extensive tabular and graphical data on such subjects as "Kinetics of the Systems of Wolfram Carbide, Titanium Carbide, Chromium Carbide," and "Modern Shipbuilding Techniques."

Dr. Gordon N. Scott, consulting engineer of Los Angeles and W. H. J. Vernon, of Chemical Research Laboratory, Teddington, Middlesex, England have been selected to receive the 1955 NACE Awards. Dr. Scott, whose corrosion work goes back more than 20 years, has written many papers on cathodic protection and coating of underground and underwater structures. He is in demand as a lecturer for University courses dealing with corrosion prevention and has appeared before short course students at programs co-sponsored by the National Association of Corrosion Engineers. Dr. Scott was a contributor to the only Proceedings published by the NACE following its first annual meeting in 1944. Dr. Scott has been named to receive the Frank Newman Speller award for achievements in corrosion engineering.

Mr. Vernon, whose numerous scientific treatises on corrosion related to bacteria, inhibitors, coatings, economics and other corrosion matters have appeared in publications in England, France, Canada and the United States, has been selected to receive the Willis Rodney Whitney Award for achievements in the field of corrosion science. Mr. Vernon's acute perception of the mechanisms of corrosion has gained him a world wide reputation in his field.

ASME Nuclear Engineering Committee Established

The American Society of Mechanical Engineers has established a Nuclear Engineering Committee which it says will serve to coordinate a number of activities connected with nuclear engineering now carried out by various divisions of the society.

Committee chairman Albert C. Pasini, Detroit Edison Corp., said work will be devoted primarily to fuels, heat transfer, instruments and regulators, metals engineering, power and safety. He pointed out that activity would be more practical than in past because of increasing declassification of documents made possible under new Atomic Energy Act.

Primary assignments of committee will be to plan participation of ASME in Nuclear Engineering Conference scheduled in summer of 1955 and to study ASME long-range needs in field of nuclear engineering and recommend method of organization within society.

It was emphasized that committee is separate and distinct from ASME's Nuclear Energy Application Committee which is a policy group.

A five-year index to CORROSION's Technical Section was published in December, 1950.

In 9 years CORROSION's Technical Section pages number more than 3000.

Phosphate Treatment Not Entirely Satisfactory For Some Container Uses

General use of phosphate treatments for container interiors may not be entirely satisfactory according to L. J. Nowacki, Battelle Memorial Institute, in Summary of Proceedings of Symposium on Phosphate Pretreatment held in Columbus, Ohio on April 29. Mr. Nowacki explained that the coatings actually may decrease resistance of linings to some hard-to-package products and apparently the question of phosphating must be decided only after considering each product and possibly each coating used.

Mr. Nowacki said best pretreatments of the iron phosphate type were comparable to best zinc phosphate types on over-all basis and were better in reverse-impact and ductility tests. He expressed little doubt that scale removal is necessary before phosphating and felt improved outdoor durability is an important reason for using treatment. He pointed out chromic acid rinse as necessary for best performance in salt-spray and water-immersion tests. He revealed that with few exceptions less rust occurred on metal-phosphated panels exposed to high humidity than on clean or hot-rolled steel.

Heavy zinc phosphate coatings impair reverse-impact resistance of organic linings applied over them and a maximum coating weight around 200 mg/ft² seems satisfactory with lower weights of coating necessary to withstand forming operations he said. Mr. Nowacki summarized the phosphate treatment program conducted at Battelle Memorial Institute for Steel Shipping Container Institute, Inc., by saying that pretreatments still must be considered mainly from their performance on container exteriors and in unlined containers.

The summary includes short reviews presented during the symposium by seven suppliers of metal phosphating compounds. One supplier felt satisfactory results could be obtained by using high quality hot-rolled steel having tight, uniform scale. He was of the opinion that degree of improvement obtained by using scale-free steel does not justify cost involved. Another favored more comprehensive study before definite conclusions are drawn regarding certain phases of phosphate treatments. Simplicity, economy and durability merits of iron phosphating were pointed out by a supplier. Another stated that neither iron nor zinc phosphate in themselves were of special value as rust preventives for extended periods but were of value as surface preparation for paint.

According to the summary investigations by Battelle showed best outdoor exposure resistance was obtained when enamels were applied over scale-free surface using high-quality hot-rolled steel selected from centers of sheets.

The summary is published by Steel Shipping Container Institute, Inc., 600 Fifth Ave., New York 20, N. Y.

BOOK REVIEWS

Neoprene Notebook No. 60. 8½ x 11 inches, eight pages, paper. August 1954. Products Information Service, E. I. du Pont de Nemours & Co., Inc., Wilmington, Delaware. Free.

The seventh in "Language of Rubber" series telling how rubber industry runs tests and what results mean to engineers and designers of rubber parts. Resistance of rubber to abrasion, flex fatigue and tearing are discussed. Neoprene coatings, hog drive belts and safety soles are presented. Also included are Neoprene abstracts on centrifugal pump, leveling mount and cleat conveyor belt.

•
A German-English Dictionary of Automatic Control Terms (Paper No. 54-IRD-4). 8½ x 11 inches, 18 pages, paper. 1954. Order Dept., American Society of Mechanical Engineers, 29 W. 39th St., New York 18, N. Y. Per copy, 50c.

The dictionary was compiled by D. W. Pessen, research engineer, Servomechanism Laboratory, Brown Instruments Division, Minneapolis-Honeywell Regulator Co., Philadelphia. Mr. Pessen states the aim of the dictionary is not to supplant but rather to supplement existing German-English scientific dictionaries. It lists about 750 German words and their English translations or equivalents many of which are not found in German-English scientific dictionaries. Most of the terms stem from articles in the German publication "Regelungstechnik" (Automatic Control Technology) and from recently published German Automatic Control Terminology Standard. An appendix lists German automatic control symbols and conventions.

•
Physical, Electrical and Chemical Properties of "Mylar" Polyester Film (TR-1). 8½ x 11 inches, 16 pages, paper. Film Department, E. I. du Pont de Nemours & Co., Inc., Wilmington 98, Delaware. Free.

A technical report on physical, electrical and chemical properties of Mylar polyester film containing revised, up-to-date information, with charts, diagrams and tables. Types and gauges of Mylar are listed and a table on the film's physical properties as compared to cellophane, polyethylene and acetate film produced by Du Pont is included.

•
Adhesives For Mylar Polyester Film (TR-2). 8½ x 11 inches, five pages, paper. Film Department, E. I. du Pont de Nemours & Co., Inc., Wilmington 98, Delaware. Free.

A technical report on adhesives developed for bonding Mylar to other materials containing information supplied by adhesive manufacturers. Listed in detail are adhesives recommended for bonding Mylar to other films and a directory of adhesive suppliers as well as adhesive code names and colors.

•
Permian Basin Fifth Biennial Corrosion Tour. 61 pages, 8½ x 11, Paper. 1954. Permian Basin Section, National Association of Corrosion Engineers. Available from John A. Knox, The Western Company, Midland, Texas. Per Copy, \$2.00 postpaid.
This publication is a narrative of the September 30, October 1 and 2, 1953, 5th

Biennial Corrosion Tour sponsored by NACE's Permian Basin Section. It includes descriptions of the numerous exhibits of oil well production and storage equipment in and around Midland, Texas. The equipment is described, the type of protection itemized and the degree of change from the last inspection is indicated. In some instances registrants had the opportunity to see the progress of corrosion or the advantage of corrosion control measures since 1951 on the same equipment.

Equipment inspected included asbestos cement, cement lined, inhibited, plastic coated and plastic pipe lines; refinery equipment; tanks with aluminum decks, ammonia treated, coal tar and plastic coated, concrete bottomed, galvanized, nickel plated bottomed and plastic bottomed tanks; plastic coated treaters, salt water disposal and water flood systems, and the effect on wells of alloys, cathodic protection, inhibitors and plastic coatings.

Paint Industries Show

Presentation of technical papers and discussions, including one on polyvinyl acetate emulsion paints are scheduled during the 19th Paint Industries Show to be held in Chicago on November 15-20. James Scott Long, Devoe and Reynolds Co., is to present the Joseph J. Mattiello Lecture and John T. Retaliata, president of Illinois Institute of Technology, will give the keynote address.

SAE Design Session

Four papers were scheduled during a symposium on Compatible Design of Equipment and Its Packaging sponsored by Society of Automotive Engineers Technical Committee S-8 in Los Angeles, California on October 7. The papers deal with Air Force packaging problem, fragility rating for aircraft equipment, optimum properties of a packaging material and high-speed photography as a tool in shock and vibration.

Plant Maintenance Show

The 6th Plant Maintenance and Engineering Show is scheduled to be held in New York City on January 24-27.

Inter Society Corrosion Committee

CORROSION MEETINGS

CALENDAR

Nov.

1-3 American Institute of Mining and Metallurgical Engineers, Institute of Metals Division, Fall Meeting, Sheraton Hotel, Chicago, Ill.

1-5 National Metal Exposition, Chicago, Ill.

8-11 American Petroleum Institute, Conrad Hilton Hotel, Chicago, Ill.

14-18 National Association of Corrosion Engineers, Western Regional Division meeting, Los Angeles, California.

15-18 American Gas Association, Operating Section, Organization Meetings, Hotel New Yorker, New York.

28-Dec. 1 American Society of Refrigerating Engineers (50th Annual Meeting), Hotel Ben Franklin, Philadelphia, Pennsylvania.

28-Dec. 3 American Society of Mechanical Engineers (Annual Meeting), Hotel Statler, New York, New York.

Dec.

12-15 American Institute of Chemical Engineers (Annual Meeting), Statler Hotel, New York, New York.

1955

Feb.

16-18 National Association of Corrosion Engineers (Sixth Annual Pipeliners Short Course) Mayo Hotel, Tulsa, Oklahoma.

March

7-11 National Association of Corrosion Engineers, Annual Conference & Exhibition, Palmer House, Chicago, Ill.

28-April 1, 9th Western Metal Congress and Exposition, Pan-Pacific Auditorium, Los Angeles, California.

May

1-14 American Institute of Chemical Engineers, Shamrock Hotel, Houston, Texas.

9-13 A.G.A. Industrial Gas School—(location to be announced).

16-18 Southern Gas Association, New Orleans, Louisiana.

June

5-9 Canadian Gas Association, Annual Meeting, General Brock Hotel, Niagara Falls, Ontario, Canada.

12-17 American Water Works Association Annual Conference, Chicago, Illinois.

13-18 American Society of Mechanical Engineers (75th Anniversary Meeting), Congress and Hilton Hotels, Chicago, Illinois.

Oct.

17-19 A.G.A. Annual Convention, Los Angeles, California

17-21 National Metal Exposition, Detroit, Michigan (A.G.A. will exhibit).

Nov.

13-18 The American Society of Mechanical Engineers, Congress & Hilton Hotels, Chicago, Illinois.

27-30 American Institute of Chemical Engineers (Annual Meeting), Statler Hotel, Detroit, Michigan.

1956

March

12-16 National Association of Corrosion Engineers, Annual Conference & Exhibition, Hotel Statler, N. Y., New York.

Oct.

15-16 National Metal Exposition, Philadelphia, Pa. (A.G.A. will exhibit).

29 to Nov. 1 A.G.A. Annual Convention, Atlantic City, New Jersey.

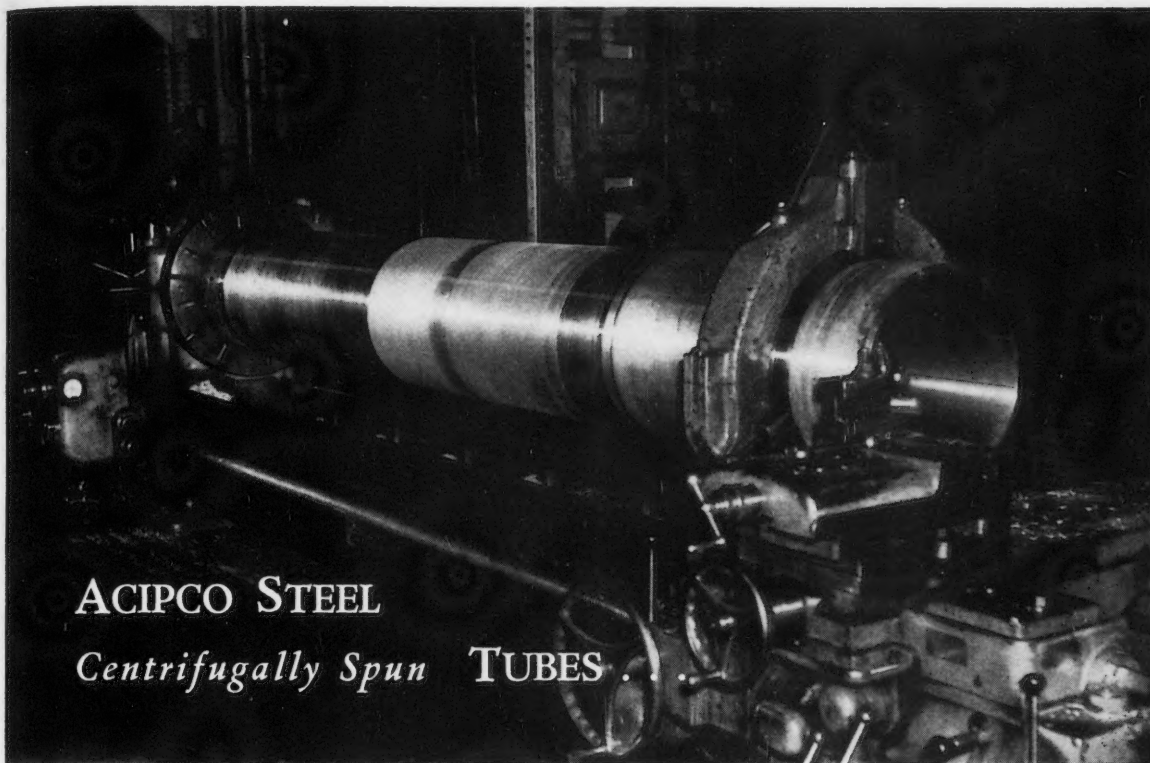
Nov.

25-30 The American Society of Mechanical Engineers, Statler Hotel, New York, New York.

1957

Oct.

21-25 National Metal Exposition, Cleveland, Ohio (A.G.A. will exhibit).



ACIPCO STEEL *Centrifugally Spun* TUBES

Can Solve Your CORROSION PROBLEMS!

TODAY, MANY MODERN INDUSTRIES are specifying ACIPCO stainless steel centrifugally spun tubes to combat the damaging effects of chemical, atmospheric, galvanic and other types of corrosion. They have found through experience that ACIPCO tubes serve exceptionally well under adverse conditions in countless industrial applications.

Manufactured to meet national standard specifications, a wide variety of sizes in lengths up to 16 feet are available and can be made to order promptly. ACIPCO tubes

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SIZE RANGES: 2 1/4"-50" O.D.; 3/8"-4" wall.

TYPES: Carbon, alloy and stainless steel, cast iron and Ni-Resist.

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NEW PRODUCTS — Materials — Service — Literature

Gredag Inc., Niagara Falls, N. Y., manufacturers of graphited and non-graphited industrial lubricants has published a four page folder "Service Recommendations for Industrial Lubricants" describing the many Gredag products.

Brass Wire produced by Titan Metal Manufacturing Co., Bellefonte, Pa., is described in a four-page folder entitled Titan Brass Wire which has been published by the company.

Ingram-Richardson Manufacturing Co., Beaver Falls, Pa., has received a contract for porcelain enameling aluminum sheets and extrusions used as bulkhead partitions on the aircraft carrier Forrestal. It reports that porcelain enameled aluminum is used as a weight reduction feature in certain parts of the ship and indicated that low maintenance and corrosion resistance features may have been factors in the material's selection.

Phoenix Precision Instrument Co., 3803-05 N. Fifth St., Philadelphia 40, Pa., produces the Sinclair-Phoenix forward-scattering aerosol and smoke photometer which it says is a rugged, portable unit designed for study, measurement and control of air pollution and particulate matter suspended in aerosols.

Proseal No. 16, a chromate conversion protective coating for aluminum and aluminum alloys produced by Promat Division, Poor and Co., Waukegan, Ill., is said to effectively inhibit corrosive action under paint films on aluminum. The coating is designed for use on any application where extruded, forged, wrought or cast aluminum and its alloys are used. The company reports that it meets requirements specified in MIL-C-5541 for military aircraft applications and that results of professional laboratory tests indicate no changes in physical properties have been noted on panels treated with Proseal No. 16 after 500 hours of exposure to 20 percent salt spray solution at 95 degrees F.

Economy-Faucet Co., 12 New York Ave., Newark, N. J., produces a sanitary faucet with Kel-F sealing rings which it says is corrosion-resistant, fume-tight and can be subjected to steam sterilization and other special cleaning operations without risk of damage. The assembly is interchangeable with the company's Universal line of hot and cold liquid dispensers with neoprene seals. It is available in stainless steel and triple chromium plated brass, with heat-resistant plastic handle.

Go-Ezy, a formula metal and chrome cleaner is said to effectively clean any metal surface without damage to adjoining painted or nonporous surfaces. It is produced by Fritch, Inc., Wickliffe, Ohio.

Use of New Metals in construction of Platecoil, a heat transfer unit, are said to broaden application of the product. According to Tranter Manufacturing, Inc., Lansing, Mich., producers of the

unit, experiments prove it can be made of Ampco alloy, Carpenter 20 alloy, Hastelloy B and Hastelloy C. Tests indicate the whole range of materials can provide Platecoils resistant to more than 200 different corrosive media the company states.

Bettinger Corp., Waltham, Mass., says that it can increase life of exhaust systems and parts subject to high temperatures three to five times by application of high temperature ceramic coatings in such areas as automotive, trucking, marine and heating equipment. It said that this development is possible by coating the entire exhaust systems, both inside and out, with a 0.001 to 0.002-inch high temperature ceramic coating which resists corroding gases and withstands operating temperatures up to a range of 2200 degrees F.

Ecr-18, a carbon remover compound is designed for heavy duty use, either hot (150 degrees) or cold, as a tank-soak solvent to clean such materials as carbonaceous deposits, oils and asphalts from internal combustion engine parts, oil burner nozzles, Diesels, turbines, aircraft engines and automotive engines. Ecr-18 is the Orthodichlorobenzene-Cresol type formulation of U. S. Air Force Specification 20043A type. John B. Moore Corp., P. O. Box 3, Nutley 10, N. J., producers of the compound report that chromate inhibitors have been replaced by equally effective but less toxic types. The company also manufactures ST-35 which it says is a heavy duty detergent with excellent wetting and cleansing action. It has been found to be extremely effective in dilutions of two ounces to six ounces of water for cleaning floors, truck and trailer bodies and in building maintenance cleaning the company states.

International Nickel Company of Canada, Limited, announces production of electrolytic cobalt at its Port Colborne refinery. It reports that this is the first commercial production of the product in Canada. Heretofore Inco's entire cobalt output has been marketed as oxides and salts, the company said.

The Value of a broad approach to industrial water problems through an over-all survey of process water is outlined in a six-page folder which is available from Hall Laboratories, Inc., Hagan Bldg., 323 Fourth Ave., Pittsburgh 30, Pa.

A Chain Sling made entirely from Monel metal for use in handling large parts, baskets or containers in and out of picking tanks, degreasing solutions or acid baths is produced by Stanwood Corp., 4819 W. Corland St., Chicago 39, Ill.

Firth Sterling, Inc., 3113 Forbes St., Pittsburgh 30, Pa., produces zirconium which it says will meet industry's severest corrosion problems involving acids and alkalis. It is available in rods, sheet, plates, tubes, strip and wire.

Dorfan Impingo Filter for cleaning hot, wet and corrosive gases and air is de-

scribed in an eight-page brochure available from Mechanical Industries, Inc., 942 Grogan Bldg., Pittsburgh 22, Pa.

The DeVilbiss Co., 300 Phillips Ave., Toledo 1, Ohio, manufactures the DeVilbiss catalyst spray gun which it says will simultaneously spray plastic resin and catalyst. It explains that resin is fed to gun through fluid line and catalyst is introduced through air stream. The gun has one head and when gun trigger is actuated, catalyst and resin meet outside the air cap and are atomized uniformly. To assure uniform mixture a single pressure control is installed for resin and a double pressure control for the catalyst which is the governing agent in setting resin. Dual atomizing air pressure control is provided to insure uniform results regardless of main line pressure variation, the company states. DeVilbiss Company also produces paint heaters which are said to provide maximum efficiency in large or small painting operations. An axial flow, magnetic type pump for circulating hot water is the unit's only moving part. Material to be sprayed is heated in a heat transfer unit located near spray section. The company reports that exchange from hot water to material is positive and speedy and that paint cannot become overheated. It says that high degree of efficiency achieved can be attributed to the completely closed system. Each heat exchanger will heat up to 32 ounces of material per minute and paint lines in the exchanger can be cleaned by flushing with a small amount of thinner.

Mogul Turbo-Jet, a general purpose metallizing gun used to spray hard and soft metals is said to be flexible enough for use in all spraying operations. Manufactured by Metallizing Company of America, 3520 W. Carroll Ave., Chicago 24, Ill., the gun weighs 5½ pounds and may be used in a tool post or hand operated. Dual feed rolls, individually driven, eliminate possibility of wire slippage through gun and provide more positive feed, the company says. It sprays a fine, dense coating using wire from 20-gauge to 3/16-inch ranging from highest melting point molybdenum to lowest melting point wires and operates on acetylene, propane or natural gas (15 lb. psi). A magnetic controlled governor provides controlled power using 60 psi air with a wire speed range from 2½ inches to 20 feet per minute.

Erico Products, Inc., 2070 E. 61st Place, Cleveland 3, Ohio, furnishes molding service for production of fiberglass reinforced plastic parts. The molding compounds are formulated to suit requirements of each specific application and have high heat resistance and excellent physical and electrical insulating properties, the company reports. The material is suited to molding intricate shapes and a wide range of colors are available. Use of special equipment and molding techniques result in low cost moldings, the company says.

Carpenter Steel Co., Alloy Tube Division, Union, N. J., announces that the

(Continued on Page 24)

Value Plus

Days and Dollars Ahead

**design
and
installation**

Throughout industry you see more and more ALL-CO products and, little wonder, when you consider how much properly designed and installed cathodic protection equipment can save in corrosion losses.

New and improved methods are being developed and employed by ALLEN engineers to meet a variety of rigid specifications. We have designed and installed many of today's most effective cathodic protection systems. Some of them are large, others are small, but all of them are practical, dependable answers to the foe that must be fought continuously . . . CORROSION.

ALLEN'S highly trained engineers and technicians are second to none in this field and are always anxious to work with you in applying proven protective measures to your plant facilities.

**equipment
and
supplies**

The successful performance of ALL-CO products are highly rated by all who use them. Among the many products that ALLEN manufactures are the trustworthy ALL-CO Rectifiers which are built to stand up through years of uninterrupted dependable service. Oil-immersed or air cooled, ALL-CO Rectifiers are built to take it.

Other products we carry in stock for immediate shipment are Polyken tape insulating materials, corrosion testing instruments, chemical pumps, graphite, N A graphite and magnesium anodes, anode backfills and many other miscellaneous supplies.

Write, phone or wire us for more information—there's no obligation of course

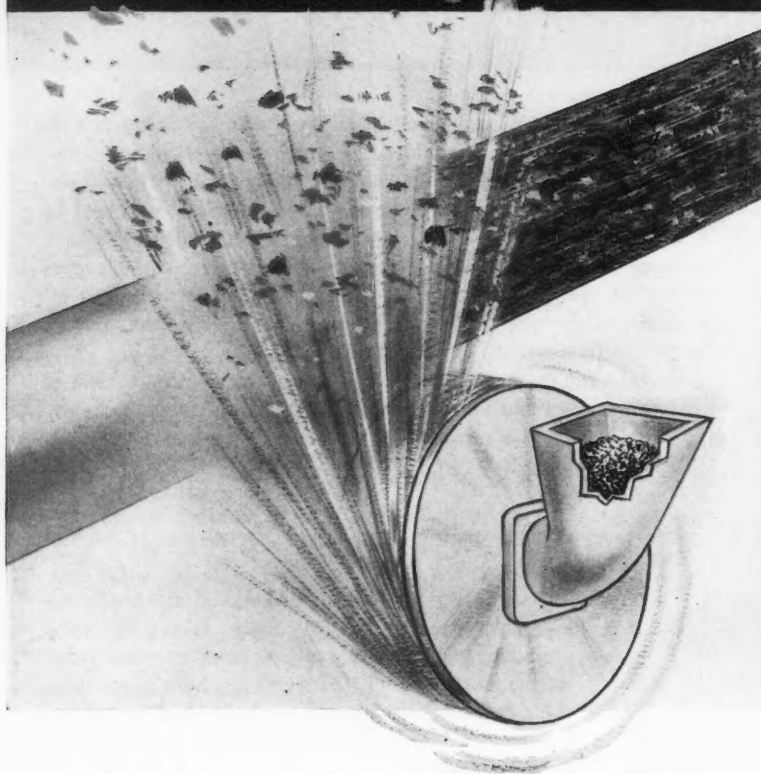
ALLEN CATHODIC PROTECTION COMPANY

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Wentworth 2651
HOUSTON, TEXAS

925 PETERS ROAD
Phone (N. O.) EDison 2081
HARVEY, LA.

BELLE CHASSE, LA.
Algiers 7497

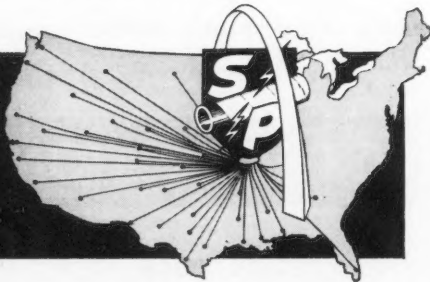
EVERY PIECE OF PIPE IS STEEL GRIT CLEANED AT *spi*



Standard Pipeprotection Inc. is the only pipe c/w plant to use steel grit cleaning on **every piece** of pipe regardless of size. Steel grit cleaning is used because it produces the perfect surface to bond the coatings to the steel. Bond performance, over the years, cannot be inspected visually or electronically.

WHY PAY THE SAME FOR LESS?

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FREIGHT
RATES AT
THE ST. LOUIS
GATEWAY



standard pipeprotection inc.

3000 SOUTH BRENTWOOD BLVD. • ST. LOUIS 17, MISSOURI

NEW PRODUCTS

(Continued From Page 22)

American Society of Mechanical Engineers has approved use of Carpenter Stainless No. 20 Cb plates, pipe, tubing, bars and forgings in welded construction. It said the product was formulated specifically for applications involving welding during fabrication and where parts must be placed in service in the as-welded condition. Stainless No. 20 Cb can be welded by any standard arc and resistance process, however, Oxy-acetylene welding is not recommended, the company says. Typical applications for the alloy include mixing tanks, heat exchangers, process piping, bubble caps, metal cleaning and pickling tanks, spray pickle equipment and others. Findings of ASME are expected to widen applications for this steel. It is available as sheet, plate, pipe, tubing and bar.

Complete Systems for pH recordings and control incorporating Beckman Model W amplifier are manufactured by The Bristol Co., Waterbury 20, Conn. The systems also include Bristol Dynamaster Potentiometer recorder and controller, electrode assemblies in either flow or immersion types and a variety of final control elements for addition of gaseous, liquid, solid or slurried reagents, the company said. It has published a 38-page bulletin (Q1304) giving engineering specifications and illustrations of each component of the systems and shows methods of installing pH instruments in a number of different applications. The bulletin is available from the company.

Metal-Cladding, Inc., North Tonawanda, N. Y., announces relocation of its offices and plant at Niagara and Miller Sts., North Tonawanda, N. Y. The company specializes in corrosion prevention and in application of custom-made coatings for the process industries, baking industry and other fields.

Arthur S. LaPine & Co., 6001 S. Knox Ave., Chicago 29, Ill., produces Lanco combined hot plate-magnetic stirrer which it says makes it possible to heat liquids while stirring magnetically. Base of unit is a light casting housing controls for heating and stirring and stirrer motor. Hot plate assembly plugs into top of base and is easily removable. Stainless steel support rod threads into base and each unit is supplied with a glass-enclosed stirring magnet. Rheostat control of motor enables "dialing in" most effective speed for stirring a particular liquid and input controller obtains variable heating from 0 to 400 watts. Both rheostat and input controller have "off" positions so stirring and heating are independent of each other and can be used separately or together. Motor and magnet are fan-cooled for long life and plug is grounded for safety.

Allyl-Phenolic Type Corrosion Resistant Linings, heat-cured protectives for storage and processing equipment are said to resist solvent, acids, oil and mineral solutions as well as alkalies, both strong and weak. While extremely hard they have good flexibility according to Stalpic Division of A. Gusmer, Inc., Woodbridge, N. J., producers of the

(Continued on Page 27)

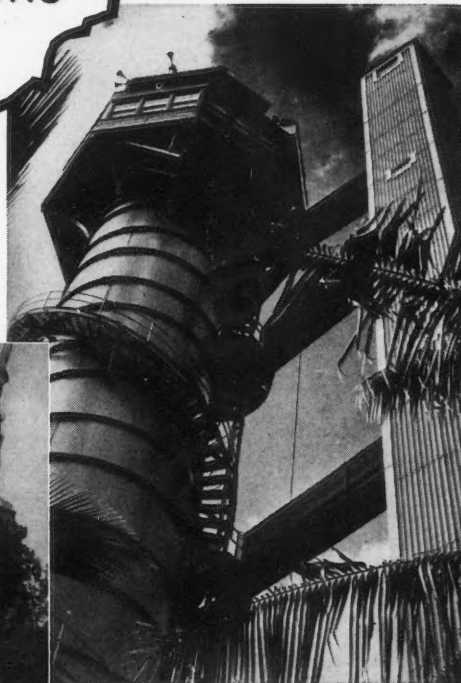
Parlon Stays On!

From Pearl Harbor to the Statue of Liberty

SCHOOLROOM FOR SUBMARINERS—Filled with 20 fathoms of water—that's a depth of 120-feet to landlubbers—this tower at Pearl Harbor is used to teach Navy men to escape from underwater. The inside has to be protected by a coating that can withstand continuous submergence, provide good visibility, yet won't rust, won't peel, won't require frequent shutdowns for repainting. For the job, the Navy selected Torex Enamel, a Parlon-based paint made by Inertol Co., Inc., Newark, N. J., and 27 S. Park, San Francisco.

BRIGHT WELCOME

—Bedloe's Island, home of the Statue of Liberty, must always look its best. To keep it that way, Ramuc Masonry Paint, another Inertol Parlon-based product, is used on the administration building and employees' quarters. Despite continual exposure to sea air and moisture, Ramuc has succeeded where previous finishes failed.



U. S. NAVY PHOTO

From Pearl Harbor to the Statue of Liberty—and all stops between—Parlon-based paints are providing better service at lower long-term cost. That's because in any climate, and under the most adverse conditions, Parlon-based paints can be counted on to stand-up. Despite blistering sun or sub-zero cold, salt sea air or corrosive fumes, paints made with Hercules Parlon (chlorinated

rubber) have what it takes to keep structures bright and clean.

For interior or exterior work; for masonry, metal or wood surfaces—there's a Parlon-based paint ideally suited for every maintenance job. For details on Parlon-based paints and case histories of their use, see your dealer or write directly to Hercules—the producer of Parlon.

Cellulose Products Department **HERCULES POWDER COMPANY** 999 Market St., Wilmington 99, Del.



**LOOK FOR THIS LABEL
ON THE PAINT CAN...**

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HERCULES® CHLORINATED RUBBER

PARLON CHLORINATED RUBBER PAINTS ARE AVAILABLE FROM 400 MANUFACTURERS UNDER THEIR OWN BRAND NAMES CR54-G

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\$11⁰⁰

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libraries of educational institutions remains unchanged*

During 1954 more than 890
pages of editorial matter will
be published in CORROSION

Send Subscriptions and Remittances to

NATIONAL ASSOCIATION of CORROSION ENGINEERS

1061 M & M BUILDING

HOUSTON, TEXAS

NEW PRODUCTS

(Continued From Page 24)

linings. It reported that they are odorless and tasteless after curing at steel temperatures from 340 to 370 degrees F, and resultant surfaces are smooth, resist deposits and are easily cleaned. Sterilizing with steam at pressures up to 10 psi has no effect on the linings, the company says.

Champion Rust Proof Primer is said to create a special pigment from the interaction of primer with rust particles which results in effective stoppage of further rust formation and allows large covering capacity for primer. Champion Bronze Powder & Paint Co., 2526 W. Van Buren St., Chicago 12, Ill., producers of the primer recommend it for rebuilding and original manufacturing work, large area or small retouching paint jobs and for protecting storage tanks, structural iron work, outdoor equipment and other similar materials.

Pantex Manufacturing Corp., Pawtucket, R. I., announces acquisition of the complete line of plug valve actuators formerly produced by Valve Controls, Inc.

V. D. Anderson Co., 1935 W. 96th St., Cleveland 2, Ohio, has published a data sheet describing three styles of air release valves used for venting air from hot water heating systems, water mains, tanks in both deep and shallow well pumping systems, water filters and systems in water works and for releasing air or gas from other liquid lines and tanks under pressure. Information is provided on standard Silvertop air release valves, forged steel Silvertop and Anderson No. "O." Included is capacity table weights, prices, cubic feet of free air handled by various valves at different operating pressures and other purchasing information.

Industrial Division of Minneapolis-Honeywell Regulator Co., Wayne and Windrim Aves., Philadelphia 44, Pa., has developed an electronic system known as servo analyzer which it says will permit engineers to estimate effect of adding new equipment to industrial operation without actually test-installing. The system automatically translates behavior characteristics of equipment to a chart record which, in turn, is analyzed to determine effect of a component on over-all behavior of operation, the company explains. It is portable and made up of a single generator, portable potentiometer, control box and function plotter and provides energy-pneumatic, mechanical and electrical tests. In addition the analyzer is used for analog tests and in development of precision controls, pipelines, refineries, air foils and jet engine components.

Bowser Technical Refrigeration, Terryville, Conn., has published a 12-page catalog describing its environmental testing and processing equipment. It includes illustrations and specifications on the company's redesigned altitude, humidity, low temperature and prefabricated test chambers as well as explosion chambers, sand and dust chambers and other specialized testing equipment.

Steel and Aluminum Products Corp., 19001 Glendale Ave., Detroit 23, Mich., (Continued on Page 28)

The New Acidizing Inhibitor

Trade Mark

RODINE

Reg. U.S. Pat. Off.

No. 203

Provides Positive Protection for

Well Tubing — Acid Storage Equipment
at high as well as low temperatures.
Designed specifically for acidizing.

An organic inhibitor;
"RODINE" No. 203 does not
contain sulphur or arsenic;
ingredients known to stimulate embrittlement.

- Not destroyed by H₂S.
- Prevents localized pitting.
- Readily soluble in water or acid.
- Needs no dispersing agent.

ECONOMICAL

EFFECTIVE

EASY TO USE

Further Details on Request

Pioneering Research and Development Since 1914

AMERICAN CHEMICAL PAINT COMPANY



Detroit, Michigan

General Offices: Ambler, Penna.

Niles, California



Windsor, Ontario

NEW PRODUCTS

(Continued From Page 27)

has been appointed a distributor of aluminum sheet, plate, rod, bar and wire produced by Kaiser Aluminum and Chemical Corporation.

Corrosion Services, Inc., announces location of plant and offices on Sand Spring Road, P. O. Box 7343, Tulsa, Oklahoma. The company distributes nationally known products for corrosion mitigation and provides consulting service on corrosion problems to industry throughout the United States.

John B. Moore Corp., P. O. Box 3, Nutley 10, N. J., announces relocation at Peerels Bldg., 384 Franklin Ave., Nutley, N. J., with mailing address remaining the same.

J. G. Sylvester Associates, Consulting Engineers, announces establishment on Route 3, 437 Whiting St., Hingham, Mass. It specializes in industrial radiography.

American Potash & Chemical Corp., announces completion of dust-proof and air-conditioned control laboratory at the Trona, California plant. The laboratory will conduct approximately 60,000 individual tests monthly of chemical solutions before, during and after processing at production plant, the company says.

Aluminum Company of America, 1501 Alcoa Bldg., Pittsburgh 19, Pa., produces an aluminum forging alloy of the aluminum, zinc, magnesium, copper series which it says will meet the urgent needs of modern aircraft. The alloy, called X7079, will offer aircraft designers aluminum forgings with greater uniformity of properties in heavy sections and a considerable increase in ductility in cross grained directions, the company states.

Cincinnati Sub-Zero Products, 3930 Reading Road, Cincinnati 29, Ohio, produces a low temperature chilling machine specifically designed for large heat treating operations. Adjustable temperature control is provided from -70 to -150 degrees F and thermal capacity is 8000 BTU's per hour at -120 degrees F which is sufficient to chill 200 pounds of steel per hour from +80 to -120 degrees F, the company reports. Instrumentation consists of recording controlling thermometer graduated from -150 to +50 degrees F. Unit is powered by 2 hp motors and features all steel construction. Chilling chamber is 36 x 42 x 36 inches deep providing 27 cubic feet of usable space.

Lee Healey Co., 554 W. Garfield Ave., Glendale, California, produces Neovane rubber impeller pumps. Unit features entire body casting of solid marine bronze with stainless steel shafts, is equipped with mechanical seal and molded in, rubber encased sleeve. Impeller is self lubricated by means of liquid pumped and impeller cover is of heavy brass, easily removed for inspection or replacement.

Increased Problems caused by disposition and treatment of waste materials by industry has prompted Kaighlin &

Hughes, Inc., piping and mechanical contractors, to organize an Industrial Wastes Division according to Lloyd I. Hughes, president. Edmund B. Bessel-vievre has been appointed manager of the division which will provide services including design, engineering and contracting to solve waste materials problems.

Palo Laboratory Supplies, Inc., 81 Reade St., New York 7, N. Y., manufactures a ball-point pen called Tech-Pen which it says writes on such surfaces as glass, metal, porcelain, paper, plastic, cloth or leather. Ink resists washing, weathering, rubbing, acids, alkalis, alcohol, autoclaving and temperatures up to 500 degrees C the company reports. Descriptive literature is available from the manufacturer.

Howell-Lanier Engineering Sales, 4703 Ritchie Hwy., Baltimore, Md., has been appointed metropolitan Baltimore distributor for Raybestos-Manhattan, Inc. The company will stock and provide engineering service for R/M industrial hose, transmission belts, V-belts, conveyor belts and other rubber products.

Nukem Products Corp., Buffalo, N. Y., has issued a bulletin on its Hi-Temperature Heat Exchangers for heat transfer of pickling solutions, plating solutions and chemical solutions which are said to offer a 15 percent saving in acid consumption. The bulletin is available on request.

Ceramic Coatings and Porcelain Enamels is a brochure listing applications of General Ceramics Corp. products. One-step enamel processing of pre-assembled water tanks is featured in the brochure which is available from the company at Keasbey, N. J.

Nickel-Aluminum Bronze—Bulletin A-133, 12 pages, includes tables of properties and illustrations of applications of zinc free, tin free, high strength copper-base alloys that have high resistance to corrosion, erosion, cavitation and wear. Corrosion resistance is reported to be higher than that of manganese, tin bronzes or red brass. The bulletin is available from International Nickel Co., Inc., 67 Wall St., New York City.

Fosbond 61, a phosphatizing compound which provides a crystalline coating on metal surfaces as a base for painting has been developed specifically for use on zinc or steel surfaces by Pennsylvania Salt Manufacturing Co., 1000 Widener Bldg., Philadelphia. It is intended to be mixed with water then applied by spraying.

Semi-Steel Mudco O-ring butterfly valves in small sizes are now being manufactured by Mud Products, Inc., Tulsa. They are quick-closing, positive seal, non-lubricated valves, made of several materials including steel, bronze, aluminum, semi-steel, ceramic lined semi-steel and stainless steel. A 16-page catalogue is available from the company.

Fluid-Fluid—Extraction is a 57-page paper in the "Dechema-Erfahrungsaustausch" series, published by the Deutsche Gesellschaft für chemisches Apparatewesen at Frankfurt/Main West 13, Postfach. Sixty-two illustrations, a short survey of extraction processes, and de-

tailed descriptions of extraction units, a reference to current literature on the subject and an index are included in the volume, which is published in manuscript form at DM 18.24 to members of Dechema and DM 22.80 to non-members with packing and handling costs DM 1. extra.

What Is Hall Laboratories?, a pamphlet on the history and facilities of Hall Laboratories, Inc., Hagan Bldg., Pittsburgh, Pa., is available without cost from the company. It describes the successful work done by the laboratories in treating industrial water and in removing troublesome impurities from it.

Cooper Alloy Foundry Co., Hillside, N. J., has expanded its production of extra low carbon stainless steel which permits welding without subsequent heat treatment.

Leak-Tec, a sensitive liquid for detecting minute leaks of gases, air, chemicals, etc., is said to be non-inflammable, non-explosive and non-injurious to the person using it. It is packaged in a polyethylene container equipped with a specially designed AGC dispenser, and is applied directly to the surface that is to be tested. Leak-Tec is manufactured by American Gas & Chemicals, Inc., International Bldg., Rockefeller Center, New York City.

Results of Field Tests on sixty different coating systems applied on rusty steel panels are listed in Bulletin No. 121, Carboline Company Division, Mullins Non-Ferrous Castings Corp., 331 Thornton Ave., St. Louis, Mo. Both primer and finish coats are listed and scored for appearance, adhesion, creep corrosion and edge protection. Panels were suspended outside in a 7 percent sulfuric acid mist at 130 degrees F developed by acid flowing over a weir. Temperatures ranged from 20 to 95 degrees F.

Wiretex Manufacturing Co., Inc., 40 Mason St., Fairfield, Conn., has issued a new catalog of its products. Included are sections on wire baskets, processing and heat treating equipment, fixtures and crates, tanks, plating and special equipment. Wiretex also has a large stock of raw materials including nickel chrome, stainless steel, aluminum, Monel, Inconel, steel, copper and brass.

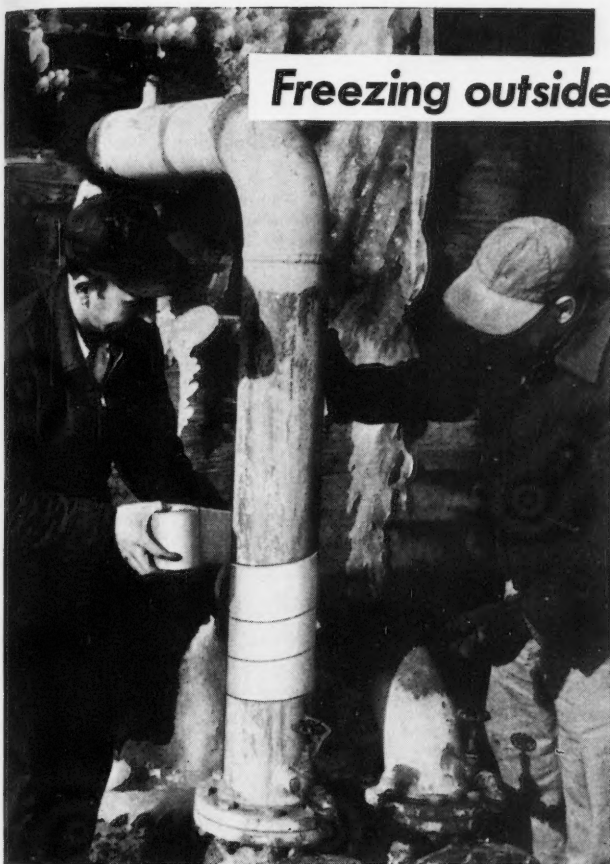
Arbonite Corp., Doylestown, Penn., is offering an information service on its new developments in the field of protective coatings. Memos are being issued on such topics as metal corrosion, electrolytic action and electric insulation. These memos together with a file folder may be had on request from The Jes-sup Associates, 243 Haverford Ave., Swarthmore, Pa.

A Teflon mechanical shaft seal is being produced by Crane Packing Co., Ltd., 617 Parkdale Ave., N., Hamilton, Ont., and Chicago, Ill. The seal is said to be able to handle practically all corrosive liquids at temperatures to 500 degrees F. Flexible sealing members are made of chemically inert DuPont Teflon. Sizes are available to specification.

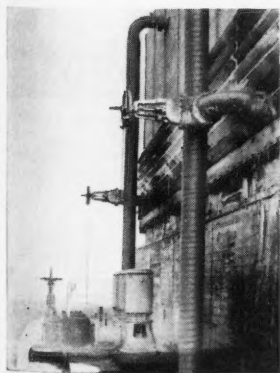
An Aluminum-Pigmented neoprene coating designed for protection of ferrous metals against atmospheric corrosion in-

(Continued on Page 30)

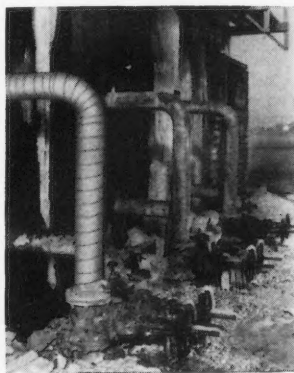
Freezing outside...130° F. inside



Cold weather . . . hot pipe . . . and still the job is easy! *Polyken* protective tape coating goes on fast and smooth, bonds tight to the pipe and to itself on the overlap with its special adhesive.



In service nine months with no sign of wear—and two men wrapped these 35-foot 12-inch pipes in less than four hours.

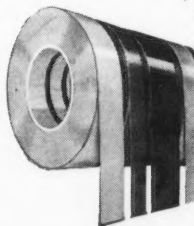


See the difference between the pipe at left protected with *Polyken* tape and rust and corrosion on pipes at right.

Polyken®

PROTECTIVE COATINGS

POLYKEN PRODUCTS DEPARTMENT OF THE KENDALL COMPANY



Polyken

PROTECTIVE TAPE COATING

BEATS

CORROSION

ON GAS TRANSMISSION LINE

The polyethylene protection of Polyken outlasts previous method 3 to 1—with no sign of wear—for Michigan-Wisconsin Pipe Line Company

Compressor Station No. 10 is a key operation of Michigan-Wisconsin Pipe Line Company.

At the cooling tower, with water reaching average temperatures of 130° F., the corrosion problem was serious. Protective paints lasted only three to four months as water used to cool gas in the line sprayed down over pipes.

The answer was *Polyken* Protective Tape Coating No. 910. Now in use for nine months, this polyethylene protection has outlasted previous methods 3 to 1, with no sign of wear, and here's why:

- *Pre-formed plastic film coating* . . . controlled process from reproducible raw materials assures uniform coatings every time.
- *Polyethylene coating* . . . 8 mils of tough, oriented, plastic film, recognized for its excellent resistance against corrosive attack and moisture, and its high dielectric strength.
- *Bonded securely* by a 4 mil stable adhesive (pre-applied to the film), a durable protective barrier in itself.

Less work to apply, too. Use it right off the roll. No heat, liquids, solvents or thinners. No drying time, clean-up time, or shut-down time. Goes on tightly and evenly with a superior bond both to the pipe and to itself on the overlap.

Polyken Protective Tape Coatings are available in two colors: black, No. 900, and gray, No. 910. Mail the coupon below for free test samples.

Polyken, Dept. C-K

222 West Adams St., Chicago 6, Illinois

Please send me samples and further information on **POLYKEN PROTECTIVE TAPE COATINGS**.

Name _____ Title _____

Company _____

Street Address _____

City _____ Zone _____ State _____

NEW PRODUCTS

(Continued From Page 28)

cluding salt spray and fumes has been introduced by Chemical Coating and Engineering Co., Darby, Pa. Seaco No. 342 is designed to combine the chemical and weathering resistance of neoprene with a reflecting non-fading pigment. Application is by brush, spray or roller. Further information is available from the company.

Frontier 40E aluminum alloy is now being used by the OPW Corp. to reduce the weight of nozzles and fittings in its equipment for handling hazardous liquids. The change resulted in a non-sparking, light weight product without loss of strength or resistance to corrosion. A data book on the alloy may be obtained without cost from Frontier Bronze Corp., 4370 Packard Road, Niagara Falls, N. Y.

Dragnet Leak Detector, a portable instrument for locating leaks in pressure piping systems is being produced by Universal Controls Corp., Dallas, Texas. The unit consists of a test pump, air storage tank, pressure gauge, transparent bubble bowl with non-freezing fluid and a flexible hose. Additional information is available from the company.

Lubricants for Corrosion and leakage resistance are described in Bulletin B K-20, published by Keystone Lubricating Co., Philadelphia. The 8-page bulletin covers lubricants used in vacuum pump cylinders, pump packing glands, plug-type valves and process piping in corrosive service. An application table and a selector chart demonstrate how the lubricants can be used to protect against 160 corrosive agents and solvents.

Aluminum Solder in wire form is now available from Belmont Smelting & Refining Works, Inc., Brooklyn, N. Y. Two alloys are available, Belmont No. 60 with a melting point about 650 degrees, and Belmont No. 40 with a melting point of about 400 degrees. Powder flux must be used with the new solder. For samples and additional information write the company.

Boltaron 6200 PVC blowers for expelling corrosive air, fumes and gases are now being produced by Industrial Plastic Fabricators, Inc., Norwood, Mass. The impeller blade is fabricated of plastic. All shaft areas and bearings are protected and sealed against corrosive attack. Details are available from the company.

A new Titanium Frit for porcelain enamel developed by Ferro Corporation is said to have high stability and to provide true color values. Porcelain enamel finishes will be as stable in color as they have been in the white form with the use of this frit, the company bulletin states.

Discussions and comments on material in CORROSION's Technical Section are welcomed for review prior to publication.

Discussions of technical material printed in CORROSION are not limited to those actually originating at the presentation of papers at meetings.

PERSONALS

Carl A. Carlsen, formerly with Scandinavian Airlines and Air Associates, Inc., has been appointed Aircraft Sales Manager, Resistoflex Corp., Belleville, N. J.

Cooper Alloy Foundry Co., Hillside, N. J., has named **Robert Lee Weidman** technical sales representative in the Mid-Atlantic states.

L. R. "Bob" Zito has been appointed district manager, west coast office, Tape-coat Co. Mr. Zito's address is 16051 Via Toledo, San Lorenzo, Cal.

John W. Conyers, Jr., formerly sales analyst for Sharples Chemicals, Inc., 1000 Widener Bldg., Philadelphia, has been transferred to the company's Market Development Department.

William D. Mathers has been named assistant manager of forging sales, Aluminum Company of America, with headquarters in the company's Cleveland plant.

Stanley L. Haines has been appointed director of industrial engineering, American Locomotive Company, Schenectady, New York.

Melbourne P. Binns has been named senior salesman for the St. Louis territory, Sharples Chemicals, Inc. His address is 80 E. Jackson Blvd., Chicago.

Seymour M. Barer has been appointed chemical engineer in the Engineering Department, Foster D. Snell, Inc., 29 West 15th St., New York City.

Willard R. Crandall has been named chemist in the Product Development Department, Foster D. Snell, Inc., New York City.

George R. Lawson, vice president, sales, Sharples Chemicals, Inc., Philadelphia, has been selected to participate in the Advanced Management Program, Harvard Graduate School of Business Administration.

A. M. Byers, Co., has inaugurated **A. B. Drastrup** as its new president. Mr. Drastrup succeeds **L. F. Rains** who has retired after 23 years as president and director of the company.

James Mauceri has been named editorial assistant for Chemical Market Abstracts, Foster D. Snell, Inc., 29 West 15th St., New York City.

John R. Morrow has joined Kaydon Engineering Corp., as assistant sales manager of the Needle Roller Division.

Calvin L. Dickinson has been named director of engineering, American Potash and Chemical Corporation, Trona, California.

James L. Murray and **Emery M. "Jock" Ellingson** have each been appointed assistant to the president, The Garrett Corp., 9851 Sepulveda Blvd., Los Angeles, California. Mr. Murray will continue as engineering representative and will report on long-range research and development projects and new products for the Air Research Divisions. Mr.

Ellingson will retain the duties of sales coordinator for airline customers and will also report on long-range planning for both military and commercial transport equipment.

Mason B. Lindsey has been named administrative assistant to the manager of the Research and Development Department, American Viscose Corp., 1617 Pennsylvania Blvd., Philadelphia.

Herschel H. Cudd has been elected vice president in charge of Research and Development, American Viscose Corp., Philadelphia.

Robert S. Dalrymple, formerly with Hanford Atomic Products Operation of General Electric Co., is now corrosion engineer in the Products and Applications Dept., General Sales Office, Reynolds Metals Co., Louisville, Kentucky.

Robert L. Bell, formerly superintendent of metals, Carbology Department of General Electric Co., has been appointed manager of manufacturing engineering.

John L. Porter has been named assistant director of the chemical research department, Kaiser Aluminum and Chemical Corporation, Oakland, California.

Reilly Tar and Chemical Corp., has appointed **Robert S. Hinkle** as a member of the company's Protective Coating Sales Group.

Leroy S. Young has been named assistant district manager of the Detroit Sales office, Kaiser Aluminum and Chemical Sales, Inc. **Leon A. Seeber** succeeds Mr. Young as branch manager of the company's Minneapolis sales office.

H. J. Beattie, Jr., physicist, Thompson Laboratory and **F. L. VerSnyder**, supervisor, metallography and high temperature testing, small aircraft engine laboratory, both of General Electric Company, West Lynn, Mass., have been awarded the 1954 Henry Marion Howe medal for a co-authored paper entitled "Microconstituents in High Temperature Alloys." The article was published in the 1953 Transactions of the American Society for Metals.

William F. Rooney has been put in charge of the Portland, Oregon office, Ebasco Services, Inc.

Dearborn Chemical Co., Merchandise Mart Plaza, Chicago, has appointed **Joseph G. Surcheck** as senior research leader, rust preventives. Mr. Surcheck will continue his duties in the field technical service division and assisting in the maintenance of field contacts with suppliers and governmental agencies.

Walter M. Goldhamer, vice president of Superior Die Casting Co., Cleveland, received the Doehler Award, highest prize of the die casting industry, during the American Die Casting Institute's 26th Annual Meeting in Chicago recently.

Mechanical Industries, Inc., 541 Wood St., Pittsburgh 22, Pa., has appointed **Walter J. Assel** engineering consultant on smoke, dust, fume and gas control problems pertaining to steel mills and electric furnaces.

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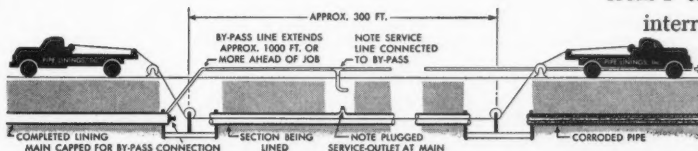
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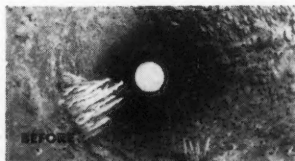
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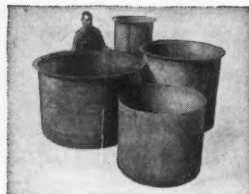
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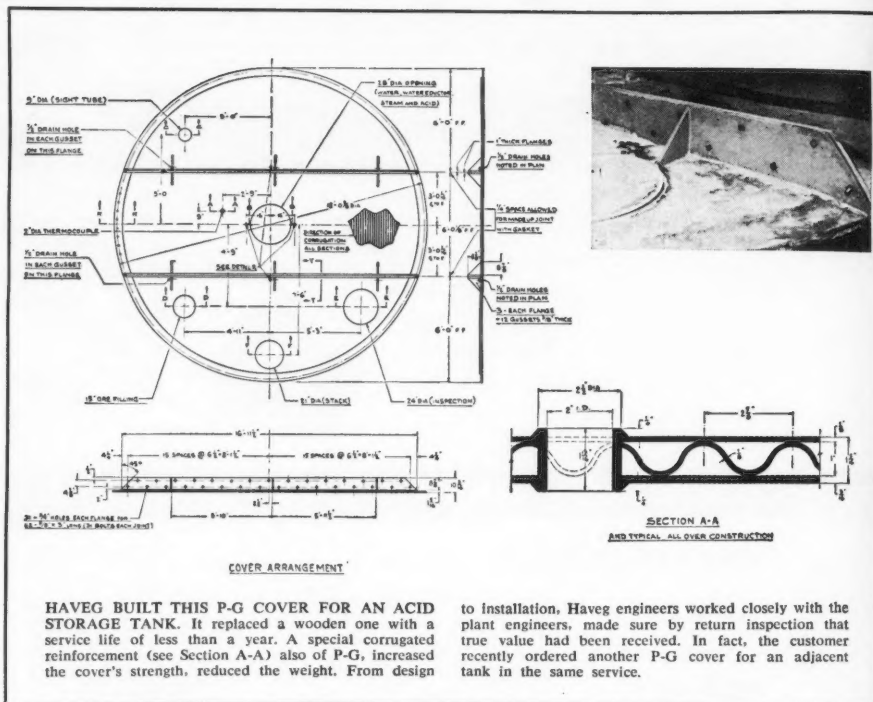
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Corrosion Abstracts

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2. TESTING

2.3 Laboratory Methods and Tests

2.3.5, 2.4.3, 5.2.1

Corrosion Voltmeter. *Ind. Chemist*, 30, 83 (1954) Feb.

Potentials liable to cause electrolytic corrosion are measured by the Cambridge Corrosion Voltmeter, an instrument developed by Cambridge Instrument Co. Ltd. and Cathodic Corrosion Control Ltd. The instrument incorporates a high resistance unipivot voltmeter together with a potentiometer which is connected in series with the "corrosion" voltage to be measured. 7535

ANNUAL INDEXING

An index to Corrosion Abstracts is published annually in the December issue. This index, in tabular form, lists the subject headings of the NACE Abstract Filing System and indexes the pages on which abstracts classified under the headings have been published during the year. It is convenient to bind this annual index with the collected abstract sections for the year so ready reference may be made to the abstracts therein.

2.3.6, 2.3.9, 6.3.19

Examination of Metal Surfaces with the Electron Microscope and by Electronic Diffraction. (Experimental part: Dr. Laske). K. HUBER. *Metallurgia Italiana*, 46, 41-48 (1954) Feb.

Electronic rays afford an important means for the investigation of metal surfaces. Of particular interest is the combination of the single research methods: microscopy and electronic diffraction (by rasant incidence and by transparency on isolated layers), and the replica method. This combination offers the means for drawing otherwise impossible detailed conclusions on the chemistry and morphology of metal surfaces. The results obtained, i.e. in the case of zinc, are original and even surprising, and show what deep knowledge could be attained by the aid of electronic rays. —MI. 7537

2.3.7, 3.5.8

An Appraisal of the Prot Method of Fatigue Testing. H. T. CORTEN, T. DIMOFF AND T. J. DOLAN. University of Illinois. Paper before ASTM, 57th Ann. Mtg., Chicago, June 13-18, 1954. ASTM Preprint No. 69, 1954, 20 pp.

The Prot progressively increasing load method of fatigue testing was investigated by comparing the experimental results for ingot iron, SAE 2340 steel (containing 3.48% nickel), 14-50 steel, and an aluminum alloy with conventional fatigue data. Both notched and unnotched specimens were studied. Prot method of fatigue testing appears promising for rapid estimation of the endurance limit of ferrous metals. Tables, graphs and 17 references.—INCO. 7540

2.3.7, 5.4.5

Instrumental Methods of Testing Organic Finishes. J. E. HYLER. *Org. Finishing*, 15, No. 1, 9-22 (1954) January.

A comprehensive review of wet film gauges, thickness testers, hardness, viscosity and adhesion testers, reflectometers, electron diffraction instruments, spectrophotometers, color testers and weathering testers.—EL. 7536

2.4 Instrumentation

2.4.3, 6.2.5

Test Determines Presence of High Residual Stresses in Stainless. H. KIRCHIK. Gen. Electric Co. *Iron Age*, 173, No. 13, 130-133 (1954) April 1.

A positive test was developed for Type 410 stainless steel to determine whether stresses are high enough to cause cracks in subsequent service. It can help to determine proper heat treatments to relieve stresses. H₂Se, formed by reaction of selenium dioxide and hydrochloric acid on 12% chromium steel, speeds crack formation if high stresses are present. Such cracks are easily identified by Magnaflux inspection. Degree of stress is determined by study of exposure time and temperature of solutions. Illustrations.—INCO. 7548

3. CHARACTERISTIC CORROSION PHENOMENA

3.2 Forms

3.2.2, 6.2.3, 6.2.4, 6.2.5

The Significance of Hydrogen in Steel Manufacture. K. C. BARRACLOUGH. *Murex Review*, 1, No. 13, 305-351 (1954).

Effects of hydrogen in steel, together with an indication of the means which may be useful in preventing excessive amounts of hydrogen from entering the steel, are discussed. Determination of hydrogen in steel by the vacuum fusion process, sampling of liquid steel for determination of hydrogen, hydrogen content of various types of steel, including carbon, 1-3% nickel, nickel-chromium-molybdenum, chromium-molybdenum, chromium, and 18-8 steels, effect of hydrogen on the solidification of liquid steel, and the unsoundness in ingots, including blisters, inclusions, porosity, seams, and segregations, are covered in detail. Very little effect due to hydrogen can be detected in stainless steels. Effect of maximum stress on susceptibility to hydrogen embrittlement was studied for the various steels. Graphs, tables, photomicrographs and 13 references.—INCO. 7531

3.2.2

The Effect of Hydrogen on the Tensile Properties of Steel. J. D. HOBSON AND J. HEWITT. *J. Iron Steel Inst.*, 173, Pt. 2, 131-140 (1953) Feb.

Further investigation of the factors

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governing hydrogen embrittlement of steel. In addition to the influence of microstructure and heat-treatment investigated in the earlier work, temperature and rate of testing are important variables. Relative immunity of austenitic steels to hydrogen embrittlement is confirmed and the relationship between hydrogen embrittlement and diffusivity is considered. A tabulation of the analyses of the steels used gives the nickel

content. Illustrations, 13 references.—INCO. 7114

3.2.2

Some Observations on the Mechanism of Pitting Corrosion. R. MAY. *J. Inst. Metals*, 82, 65-74 (1953) October.

Discusses nature of corrosion products, causes and controlling factors using copper specimens. Diagrams.—BTR. 7098

3.2.2, 3.8.4

Diffusion of D₂ From D₂O Through Steel. FRANCIS J. NORTON. *J. Applied Physics*, 24, 499 (1953) April.

Briefly describes experiments to show that hydrogen in water participates in the initial corrosion rather than the hydrogen present in the steel.—BTR. 7334

3.2.3, 3.8.4

Theory of Scaling Processes on Metal Alloys. (In German). KARL HAUFFE. *Arch. Eisenhüttenw.*, 24, No. 3/4, 161-171 (1953) March-April.

Shows how formation of metal oxides, sulfides, or halides may be a diffusion phenomenon. Suggestions for developing scale-resistant alloys. Graphs, diagrams. 97 references.—MR. 7181

3.2.2, 6.3.6, 3.7.2

Theoretic and Experimental Study of Some Phenomena of Dezincification in Brasses. Part II: Means for the Prevention of the Dezincification Phenomena. P. LOMBARDI. *Metallurgia Italiana*, 46, 91-102 (1954) March.

Following the first part of his article describing the action of the phenomenon of dezincification, in this second part the author reports the studies carried out to the aim of eliminating or reducing the occurrence of the phenomenon itself. From experiences gathered it is shown that the phenomenon can be retarded by the addition of some components, called inhibitors, to brasses.

The author describes the behavior of these various components among which the most known and applied in practice are: arsenic, antimony and phosphorous. An attempt is finally made to explain the behavior of the inhibitors which are added in meanest proportions, the explanation

being based on mechanical protective phenomena, and above all on electrochemical phenomena.—MI. 7563

3.2.3, 6.3.10

Appearance of a Special Type of Surface Microstructure in a Nickel-Chromium Alloy Subjected to Selective Oxidation. J. BENARD AND J. MOREAU. *Compt. Rend.*, 238, 1659-1661 (1954) April 21.

Alloy with 4.6% chromium was prepared by fusion under argon, heated for several hours in hydrogen at 1200°C, and then, at same temperature, in hydrogen-water vapor mixture. It formed continuous, slightly granular Cr₂O₃ film. On continuing the treatment, surface showed wide areas covered with coating invisible under microscope, identifiable by electron diffraction. Surface had parallel bands, direction of which seemed to be related to lattice orientation. In general, each crystal had only one family of bands, corresponding to the intersections of a family of (111) planes with the free surface. This is explained as due to removal of chromium atoms near surface by selective oxidation of chromium.—INCO. 7527

3.2.3, 6.3.10, 3.8.4

Rate of Oxidation of Three Nickel-Chromium Heater Alloys Between 500° and 900°C. E. C. GULBRANSEN AND K. F. ANDREW. Westinghouse Res. Labs. Paper before Wrightsville Beach Mtg., Sept. 13-16, 1953. *J. Electrochem. Soc.*, 101, No. 4, 163-170 (1954) April.

Rates of oxidation of 3 heater alloys of 80% nickel-20% chromium were studied over a range of 500-950°C. and at a pressure of 7.6 cm. of Hg or oxygen, using the vacuum microbalance method. Temper color films were obtained for all oxidations below 850°C. while gray-green films were obtained at 850°C. and higher. No evidence was found for sealing or cracking of the oxide from the alloys on cooling at temperatures of oxidation up to 950°C. Rates of oxidation were studied as a function of time and temperature, and data were related to the parabolic rate law and the classical theory of diffusion. Results are tabulated. Graphs and 20 references.—INCO. 7561

3.3 Biological Effects

3.3.4, 8.4.3, 1.6

Petroleum Microbiology. ERNEST BEERSTECHE, JR. Elsevier Press, Houston. 375 pp., 195, 6 x 9 inches. Per copy \$8.

While much of the material in this book is related to the geological aspects of microbiology as it pertains to petroleum technology, significant portions pertain to the biological characteristics of such items as drilling mud and activities of microorganisms in petroliferous structures. For example a discussion of the effect of sulfur bacteria and algae in formations, the effect of iron bacteria and the effect of sulfate reducing bacteria in Chapter 7 is likely to include information significant to the corrosion engineer.

Chapter 8, The Role of Microorganisms in Corrosion, covers theoretical considerations, aerobic and anaerobic organisms, bacterial corrosion in petroleum engineering, microbiological deterioration of nonmetallic oilfield equipment and ends with references. There is a glossary, author index, microorganism index and subject index. 7529

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3.4 Chemical Effects

3.4.10

Influence of Organic Detergents on Metal Corrosion. T. K. ROSS. *Metal Treatment*, 20, No. 91, 183-187 (1953) April.

Organic agents take an active part in the corrosion of metals, being either protective or, on occasions, destructive. The development of these detergents and some of the more active agents encountered in commercial detergent preparations are discussed. Properties of these agents are reviewed and their reaction to various metals is reported. Actual progress of corrosion in the presence of detergents is examined in the following manner: simple wetting, simple reaction with metal, adsorption on metal, breakdown of adsorbed film and action of detergent upon corrosion products. Graphs and 8 references.—INCO 6951

3.5 Physical and Mechanical Effects

3.5.2, 3.5.3, 3.5.8

The Influence of Oxide and Lubricant Films on the Friction and Surface Damage of Metals. W. HIRST and J. K. LANCASTER. *Proc. Roy. Soc., A*, 223, 324-335; disc. 335-338 (1954) May 6.

Protection afforded by oxide film against surface damage during sliding of two metal surfaces depends on geometrical sliding arrangement used. Investigation was made of variation of coefficient of friction with load. Deviations from Amonton's first law were found. Data are given for both lubricated and unlubricated friction experiments on copper, nickel and 18/8 stainless. Effects of both lubricants and preliminary surface oxidation of metals are discussed.—INCO 7539

3.7 Metallurgical Effects

3.7.3, 3.5.8, 6.4.2

The Influence of Extrusion Direction on the Corrosion and Stress-Corrosion of Aluminum-Copper-Magnesium Alloys. E. A. G. LIDDIARD and W. A. BELL. *J. Inst. Metals*, 82, Pt. 9, 426-432 (1954) May.

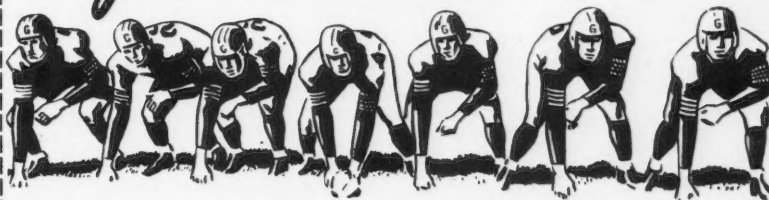
Studies with extrusions and sheet from an aluminum alloy containing 4% copper, 0.8% magnesium and 0.08% and 0.76% manganese showed that: in the fully heat-treated condition, extrusions show little, if any, susceptibility to stress corrosion when the stress is parallel with the direction of extrusion, whereas sheet is susceptible whether stressed parallel with or normal to the rolling direction, specimens cut transversely from extruded bar show susceptibility to stress corrosion equal to that of sheet material; variation in susceptibility is attributed to directionality in structure which is less marked in low-manganese material; and stress corrosion is not influenced by the thickness of the specimen and is prevented by spraying with commercial purity aluminum or aluminum=1% zinc alloy.—INCO 7568

3.7.3, 5.4.5

Weld Seam and Weld Flux Effect on Metal Surface and Coating Life. A. J. LIEBMAN. *Corrosion*, 10, No. 5, 147-150 (1954) May.

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byproducts deposited on weld seam and adjacent areas frequently are the cause of early failure of coatings on welds. Close observation by the author indicates many paint failures previously believed to have resulted from residual stresses in weld areas can be attributed to the effects of weld heat oxides, weld flux, spatter and weld flux fume deposits.

Careful cleaning of weld flux deposits from the weld itself and from adjacent areas either by impact tool, wirebrushing, pickling or best of all by sand blasting is recommended. A flame cleaning pass is recommended whenever moisture is present.

Extra thick vinyl pretreatment coatings followed by a mastic and finish coat

are helpful in prolonging protection given metal from the environment when flux deposits are inadequately removed.

Preweld oiling of areas adjacent to welds will reduce time needed for removing flux byproducts to 25 to 30 percent of time required for cleaning areas not pretreated. Preweld oils must be compatible with paints to be used. Grinding flat of exceptionally rough welds and weld striping to increase coating thickness are advocated. 7565

3.7.3, 6.3.4

Effect of Heat Treatment Upon the Microstructure and Hardness of a Wrought Cobalt-Base Alloy Stellite 21 (AMS 5385). F. J. CLAUSSE AND J. W. WEETON. Lewis Flight Propulsion Lab.

Nat'l. Advisory Comm. Aeronaut., Tech. Note No. 3107, 26 pp., March, 1954.

Study of the response of wrought Stellite 21 (28.75% chromium, 3.01% nickel, 61.1% cobalt) to heat treatment was made. 72 hours at 2250°F. was sufficient for effective solution treatment of this alloy. Pearlitic structures formed at grain boundaries of solution-treated specimens during isothermal transformation at 1950°, 1750°, and 1500°F. Widmanstaetten structure also formed during transformation at 1750° and 1500°F. Little visible precipitate formed by transformation at 1200°F. for times up to 72 hours. Water quenching from 2250°F. followed by aging at 1200-1950°F. resulted in precipitation principally along slip lines and twin boundaries. Spheroidization and agglomeration of precipitates occurred as low as 1500°F. Isothermal or aging treatments above 1200°F. increased the hardness of the solution-treated specimens. Maximum hardness of Rockwell C-42 was developed by aging 72 hrs. from 1400-1500°F., as compared to Rockwell C-20 to C-22 for the solution-treated condition. Overaging or softening occurred within 72 hrs. at 1750°F. and above for aging, and 1950°F. for isothermal transformation. Graphs, photographs, and 17 references. (See also card No. 7546, classified 3.7.4, 6.3.4, 3.7.3.)—INCO. 7545

3.7.4, 6.3.4, 3.7.3

Relation of Microstructure to High-Temperature Properties of a Wrought Cobalt-Base Alloy Stellite 21 (AMS 5385). F. J. CLAUSSE AND J. W. WEETON. Lewis Flight Propulsion Lab. Nat'l. Advisory Comm. Aeronaut., Tech. Note No. 3108, 49 pp., March, 1954.

Investigation was conducted to determine the effects of microstructure on the stress-rupture life of heat-treated wrought Stellite 21 under stress and temperature conditions comparable to those encountered during engine operation of turbine blades, and to correlate such properties as stress-rupture life, hardness, and ductility with microstructure. Results obtained, although specifically for Stellite 21, lead to conclusions that are believed to have general significance in the heat-treatment of other high-temperature alloys. Tables, graphs, photomicrographs and 7 references.—INCO. 7546

5. PREVENTIVE MEASURES

5.2 Cathodic Protection

5.2.1, 1.2.2

Economics of Cathodic Protection. WAYNE A. JOHNSON. *Petroleum Engr.*, 26, D-18-D-19 (1954) May.

Basic cost of corrosion leaks should include 1). Actual cost of repair, 2). Cost of lost products and 3). Property damage. Specific example cited where leaks in five miles, 4½" O.D. bare pipe were stopped after twenty had occurred in six and one half years by application of cathodic protection. Total cost of protection for ten years was paid out in three years. 7554

5.2.1, 3.6.9

Coordination of Corrosion Control. HUGH H. HAMILTON. *Corrosion*, 10, No. 6, 189-191 (1954) June.

The author urges better coordination among users of cathodic protection for corrosion control. Coordination means



*In this business—
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interchange of information regarding proposed or operating control devices. Better engineering of proposed installations is needed in many cases to permit proper coordination. Preventive or corrective measures that are reasonable and practical should be followed where underground metallic structures of more than one company are involved. An example is given of a top management committee which oversees a utility's entire corrosion control program. The author believes that adequate coordination (which is the exchange of pertinent information based on careful engineering studies of each corrosion control project and participated in by management) will lead to effective and satisfactory corrosion control. 7558

5.2.2

Cast Anodes for Cathodic Protection Are 4-Ways Better. A. GRAVER. Patrol Valve Co. *Precision Metal Molding*, 12, No. 3, 48-59, 84 (1954) March.

Advantages of permanent mold cast magnesium anodes include better control of impurities that cause self-destruction of the anode, more efficient corrosion pattern due to the fine grain structure of the casting, easier attaching because the core wire protrudes from the end, and economic replacement in connected 12-in. sections without loss of electrical efficiency. Solution potentials (includes 18% chromium-1% nickel and 18-8 stainless steels, Monel and nickel) measured in sodium chloride solution are tabulated. Illustrations.—INCO. 7559

5.2.4, 5.2.1

Comparisons of Cathodic Protection Test Methods. KIRK H. LOGAN. *Corrosion*, 10, No. 7, 206-211 (1954) July.

This paper compares the results of cathodic potential tests including and excluding IR drop and with the reference electrode both over and remote from the pipe.

Results of using the break in the current potential curve as a criterion for protection are compared with lowering the pipe potential —0.3 volt and to —0.85 volt. The criteria do not agree.

Results of increasing the test current in equal steps are compared with those obtained by increasing current by 50 percent increments. Equal current increments give smoother curves.

The necessity for equally spaced times of potential observations is discussed. This is desirable but not always necessary.

Data plotted on rectangular coordinate paper are compared with the same data plotted on semilog paper. Sometimes it is best to use both methods. 7564

5.3 Metallic Coatings

5.3.4, 6.4.2

New Process Electroplates Nickel Directly on Aluminum. S. G. BART. *Canadian Metals*, 17, No. 6, 42 (1954) May 20.

New process for applying nickel directly to raw or anodized aluminum affords an erosion-resistant surface and strengthens the aluminum. The need for an intermediate bonding material, such as copper or adhesive cements, is eliminated. Hardness of the deposit can be varied from 150-550 Vickers. The process was developed by Bart Labs.—INCO. 7530

5.4 Non-Metallic Coatings and Paints

5.4.8

Paints Incorporating Natural Rubber. *Corrosion Prevention & Control*, 1, No. 2, 105-112 (1954) April.

Rubber paints, divided into groups of oxidized, cyclized, and chlorinated rubber paints, are discussed at some length. Cyclized or isomerized rubber is used in heat resistant paints, chemical resistant undercoats and finishes, anti-corrosive primers, primers for plaster and cement, primers for concrete and other alkaline surfaces and floor enamels. Major applications of the chlorinated rubber paints are for the protection of metal surfaces subject to severe corrosion conditions, especially under chemical and marine conditions, also for the painting of strongly alkaline surfaces and protection of building surfaces against chemical attack. This paint is resistant to most alkalis and acids in industry, fumes and acid-laden steam.—INCO. 7544

5.8 Inhibitors and Passivators

5.8.4, 4.3.2

Corrosion Inhibition in Acid Solution. C. V. KING AND E. HILLNER. *J. Electrochem. Soc.*, 101, No. 2, 79-83 (1954) Feb.

Cylinders of iron, zinc and cadmium were rotated in a highly corrosive solution of acid containing nitrate ion as depolarizer. Three kinds of inhibitors were added to the solution: dichromate

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ion plus complexing or chelating agents for metal ions, a wetting or emulsifying agent which is strongly adsorbed; and a reagent which forms a very insoluble precipitate with ferrous and ferric ions. Measurements of the effectiveness of these inhibitors are given.—ZDA. 7549

5.8.4, 4.4.6

Neutral and Basic Sulfonates Corrosion-Inhibiting and Acid-Deactivating Properties. H. R. BAKER, C. R. SINGLETERRY AND E. M. SOLOMON. *Nav. Res. Lab. Ind. & Eng. Chem.*, 46, No. 5, 1035-1042 (1954) May.

Report presents the results of an evaluation of the neutral dinonylnaph-

thalene sulfonates as rust inhibitors in petroleum and in diester oils, and of an exploratory investigation of special properties of the basic barium soap as a rust inhibitor in acid environments. Tables give results of static-water-drop test, NRL fog cabinet test, and the brass-steel galvanic corrosion test for the reference petroleum sulfonate and the corresponding dinonylnaphthalene sulfonate. For the study of rust inhibition by alkaline barium dinonylnaphthalene sulfonate the static water-drop test was modified by substituting dilute solutions of organic or inorganic acids, or of synthetic sea water, for the distilled water of the standard method. Possible corrosive

effect of these additives on metals, including a magnesium alloy, aluminum alloy, copper, cadmium-plated steel, and steel in series electrical contact in the order named was studied. Tables, graphs and 22 references.—INCO. 7532

5.9 Surface Treatment

5.9.2, 8.8.5

Maintaining Efficiency in Trichlorethylene Degreasing Plants. E. E. HALLS. *Product Finishing*, 7, No. 3, 55-59, 118 (1954) March.

Review of practical applications of trichlorethylene degreasing and plants therefor. Reference is made to materials of construction, which include galvanized iron, lead, copper and Monel. Neither lead nor Monel is a suitable substitute for galvanized iron, which is normally used in degreasing plant construction. Copper may be suitable where heavy contamination with water is inevitable. Corrosion data for the four metals in trichlorethylene are given.—INCO. 7560

5.9.2, 6.2.5

Inhibited Pickling in Production. R. O. BAILEY. *Am. Chem. Paint Co. Steel Processing*, 40, No. 4, 229-230, 252 (1954) April.

Inhibited pickling of various steels is discussed. For stainless steels, which are not as easy to pickle as mild steels, 2 pickling procedures are recommended. Proper inhibition is effective and helps suppress embrittlement of stainless steels. Following the pickling procedure, both the 300 and 400 series of steels must be passivated by immersion in nitric acid to develop an oxide surface on the steel.—INCO. 7534

5.9.3, 6.4.2, 3.2.3

The Beilby-Layer (Die Beilby-Schicht). BORGE LUNN. *Z. Metallkunde*, 45, No. 2, 92-93 (1954) February.

Investigations concerning the "Beilby-layer" which originates in mechanical polishing, showed that it consists of a mixture of metal and metal oxide. This explains the extraordinary qualities of the Beilby-layer and a connection with the new aluminum-oxide aluminum-alloys (SAP) is mentioned. The discovery of oxygen concentration in slip planes supports the hypothesis on the influence of oxidation for interfacial processes which are of importance in bearing materials and bearing lubricants.—ALL. 7562

6. MATERIALS OF CONSTRUCTION

6.2 Ferrous Metals and Alloys

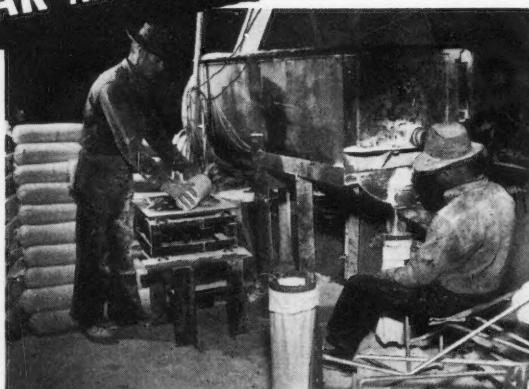
6.2.2

Where Pearlitic Malleable Irons Can Be Used to Advantage. C. F. JOSEPH. *Gen. Motors Corp. Materials & Methods*, 39, No. 3, 100-103 (1954) March.

Pearlitic malleable castings are competing favorably with other metal forms in the automotive, ordnance, aircraft and other industries. Illustrations of some of the applications show the outstanding properties, such as good machinability, selective hardening, good wear resistance, composite castings, high yield

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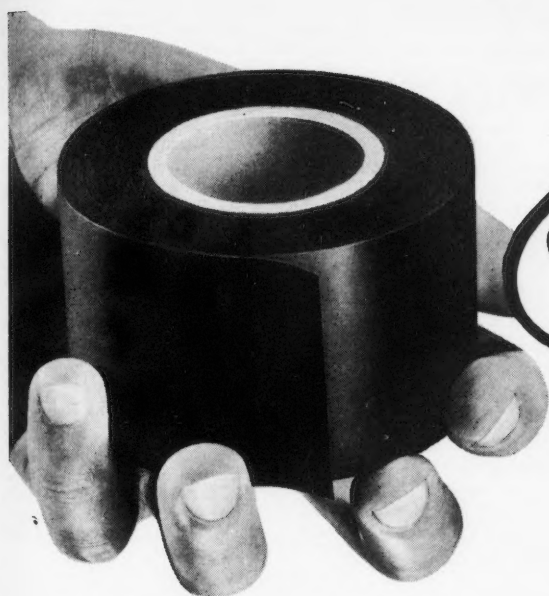
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Tensile strength lbs. per inch	30	56
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strength and excellent finishing qualities, and the reasons why castings are advantageous to other existing methods of fabrication. In the parts illustrated, pearlitic malleable castings replaced SAE 1035, 1020, 1040, 5140, 1145 and 1151.—INCO. 7552

6.2.2, 3.7.3, 3.5.9

Effect of Heat-Treatment on the Brittleness of High-Purity Iron-Nitrogen Alloys. B. E. HOPKINS AND H. R. TIPLER. B. I. S. R. A. Alloy Steels Com., Paper MG/A/1/54. *J. Iron & Steel Inst.*, 177, Pt. 1, 110-117 (1954) May.

Results of tensile and notch-impact tests on 2 high-purity iron-0.01% nitrogen alloys with .006% nickel at temperatures spanning the tough-to-brittle transition are discussed. The intergranular weakness encountered on adding nitrogen to iron may be almost entirely removed by furnace-cooling from the austenitic region, but its severity is enhanced by increasing the rate of cooling. Maximum embrittlement of the grain boundaries is developed well inside the α solid solution field at 600-700°C, water-quenching from these temperatures resulting in remarkably low brittle-fracture stresses. This extreme brittleness could be caused by grain-boundary segregation of nitrogen, which tends to be dispersed at higher and lower temperatures. There is a linear rise with temperature in the brittle-fracture stress of the material in the most brittle condition over the wide range of -196°C to room temperature. The microstructures of the alloys after various heat-treatments are discussed in the light of recently published work. 13 references.—INCO. 7538

6.2.3

Pearlite-Free Basic Bessemer Steel: Its Fabrication and Properties. A. JOSEFSSON. *Jernkontorets Analer*, 138, 225-250 (1954). *J. Iron Steel Inst.*, 177, Pt. 1, 118-128 (1954) May.

Steels with less than 0.015% carbon, termed pearlite-free, are characterized by lower impact transition temperature than steels with similar base composition and slightly higher carbon contents. Provided this carbon limit is not exceeded, up to 0.15% phosphorus and 0.020% nitrogen are used as alloying additions to give a yield strength comparable with that of plain 0.15-0.20% carbon steel without noticeable impairment of impact properties even after straining and ageing. Manganese content should be about 0.20%; higher percentages are unfavorable to low-temperature ductility after slow cooling. Pearlite-free steels of this type are shown to be easily and economically produced by the basic Bessemer process. Examples of results from impact tests on plates of these steels are given, together with results of bend tests on welded specimens. Corresponding data for plain carbon steels are included for comparison. No attempt was made to measure the resistance of pearlite-free steel to atmospheric corrosion. It is expected that it will behave similarly to rimmed carbon steel. Preliminary stress-corrosion tests in nitrate solutions showed that pearlite-free steels are only slightly better than rimmed basic Bessemer steels because of higher P content. 11 ref.—INCO. 7553

6.2.2, 2.1.2, 4.6.11

How Does Wrought Iron Stand Up in Corrosive Marine Services? J. L. WIL-

SON. *Marine Eng.*, 59, No. 2, 63-66 (1954) Feb.

Observations seem to indicate that, unless results of corrosion and wear tests correlate with service experience, such test results should be eliminated in the consideration of the application of a given material in a specific service. Similarly, something should be done to improve testing procedures in cases which result in such contradictions as now exist in the case of wrought iron as between test results and service experiences. Successful applications of wrought iron in marine service include anchor chains, boiler staybolts and pipe piling.—INCO. 7239

6.3 Non-ferrous Metals and Alloys—Heavy

6.3.6, 4.3.2

Corrosion. MARS G. FONTANA. *Ind., & Chem.*, 45, 93A-95A (1953) April.

Discusses use of copper which shows good corrosion resistance to sulfuric acid under nonoxidizing conditions. Graphs and tables.—BTR. 7040

6.3.6, 4.3.2, 5.8.4

Mechanism of Dissolution for Copper in Nitric Acid in the Presence of Certain Inhibitors. (In Russian.) S. A. BALEZIN AND G. S. PARENOV. *J. Applied Chem. (USSR)* (Zhurnal Prikladnoi Khimii), 26, No. 8, 795-801 (1953) Aug.

Substances which disintegrate nitrous acid serve as inhibitors of the rate of copper dissolution in nitric acid. Graphs, tables, 9 references.—BTR. 7496

6.3.6, 8.8.1

Copper and Copper Alloys. S. BAKER. *Metal Ind.*, 83, No. 10, 182-184 (1953) Sept. 4.

Discusses copper and copper alloys used in chemical plant construction. Grades of copper used are phosphorus deoxidized non-arsenical copper and phosphorus deoxidized arsenical copper. Valves, fittings, pumps, etc. for chemical plants are made from copper alloys. Alloys most frequently used are brasses, tin-bronze and gunmetals, aluminum-bronzes, copper-nickel alloys and silicon bronze. Copper-nickel alloys containing 20 and 30 percent nickel are used primarily as tubes and heat exchangers. Recently, alloys containing 5 and 10 percent nickel with 1-2 percent iron were developed. Photographs.—INCO. 7055

6.3.8, 8.8.1

Lead Handbook for the Chemical Process Industries. 44 pages, 8½ x 11 inches, 1954. Federated Metals Division, American Smelting & Refining Co., 120 Broadway, New York 5, New York. Gratis.

A well-designed and carefully printed book outlining in some detail the principal mechanical and chemical characteristics of lead as a material for construction in the chemical industry. Considerable emphasis is laid on the corrosion uses of the material and tables of data are given showing the order of resistance of the material to different chemicals and combinations of chemicals. Ratings are keyed to temperatures, pressures, velocities and cyclic reconstitution of lead's corrosion-limiting surface layers. After a general discussion of the reason lead is resistant to corrosives, the book successively discusses grades of lead and the various sizes, thicknesses and shapes of fabricated material produced by Federated

Metals. Details of construction recommendations for lead linings, with diagrams of common applications for both sheet lead-lined and bonded lead-lined components are given. A list of the chemicals and chemical processes with which lead is used is given and reaction of the material is graphically portrayed to sulfuric acid, temperatures, creep, and velocity of sulfuric acid. 7541

6.3.8

Corrosion of Lead. Dissolution as a Function of Time. (In German). W. KATZ. *Metallberflache*, A, 7, No. 11, 161-166 (1953) Nov.

Reports results of experiments with neutral, acid, and alkali solutions. Details of the experiments are described. Results are compared with those from electrochemical measurements. Graphs, micrographs. Five references.—BTR. 7092

6.3.9

Effects of Temperature on the Flow and Fracture Characteristics of Molybdenum. J. H. BECHTOLD. *J. Metals* (Trans. AIME), Sec. 1, 5, No. 11, 1469-1475 (1953) November.

Tensile properties of annealed molybdenum were investigated from 1000° to -200° C. In the vicinity of room temperature a well-defined transition in tensile properties occurs. Reduction in area decreases from over 80 percent to 0 percent and, simultaneously, the yield strength increases about 60,000 psi.—BNF. 7409

6.3.9, 5.3.2, 3.5.9

Nickel-Clad Molybdenum. J. LOMAS. *Machinery* (London), 82, 965 (1953) May 22.

Shows that up to 1,100° C. clad molybdenum sheets give superior all-round service to unclad molybdenum, combining high strength with resistance to oxidation. Edge protection for work at high temperatures offers no difficulty. Mechanical properties are given.—BTR. 7087

6.3.10

Chlorimet 3. W. A. LUCE. *Duriron Co. Chem. Eng.*, 61, No. 3, 254, 256, 258, 260 (1954) Mar.

Corrosion resistance data of Chlorimet 3, a 60 percent nickel—18 percent chromium—18 percent molybdenum alloy, are charted. Physical properties and applications of this material of construction in the chemical industry are covered.—INCO. 7222

6.3.10

Chlorimet 2. *Chem. Eng.*, 61, No. 2, 246, 248, 250, 252 (1954) Feb.

Chlorimet 2, 62 percent nickel—32 percent molybdenum alloy, designed to give high strength and excellent corrosion resistance under severe corrosion conditions. Corrosion resistance data of this important material of construction is charted. Physical properties and applications in the chemical industry are covered.—INCO. 7250

6.3.10

Properties of Graphic Nickel Alloy Castings. J. T. EASH AND G. L. LEE. *Trans. Am. Foundrymen's Soc.*, 61, 552-560 (1953).

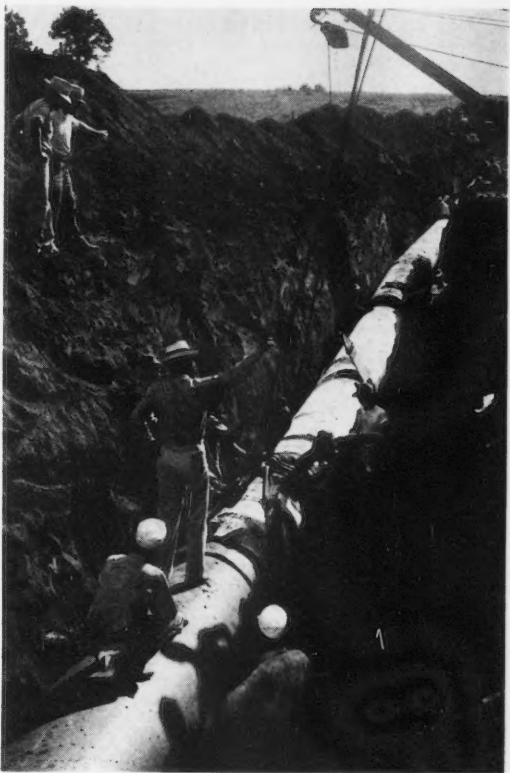
The authors describe the founding and use of castings in nickel containing 1-2.5 percent carbon, 2 percent silicon, 1.5 percent manganese and up to 0.1 percent magnesium in excess of sulfur. This material has good mechanical

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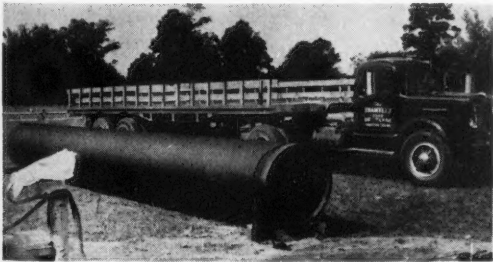


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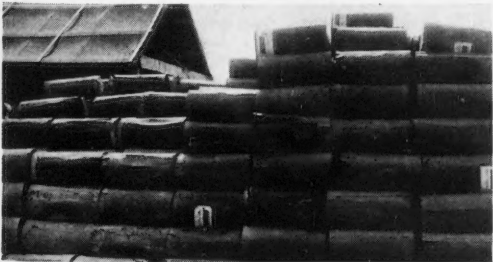
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6.3.10, 3.7.2

Aging Characteristics of Nickel-Chromium Alloys Hardened with Titanium and Aluminum—TP3692E. R. NORDHEIM AND N. J. GRANT. Massachusetts Institute of Technology. Paper before AIME, New York, Feb., 1954. *J. Metals*, Sect. 2, 6, No. 2, 211-218 (1954) Feb. (Trans. AIME, 200).

Extensive study was made of the aging characteristics of alloys based on the 80 percent nickel—20 percent chromium composition (exemplified by Nimonic 80 and Inconel X) hardened with aluminum and/or titanium each up to 4 percent. Aging was followed by means of hardness and hot electrical resistance measurements as well as by X-ray and microscopy. Stress rupture tests at 1500° F. were used as a check on the predicted behavior. Tables, graphs, photomicrographs and 10 references.—INCO. 7244

6.3.11, 3.2.3, 3.8.4

The Reaction of Silver Alloys With Sulfur in Mineral Oil. I. KINETICS. R. T. FOLEY, M. J. BOLTON, AND W. MORRILL. *J. Electrochem. Soc.*, 100, 538-542 (1953) Dec.

Traces course of reaction of silver alloys with sulfur to determine mechanism of tarnishing. Typical reaction course consisted of an initial rapid reaction similar to unalloyed silver followed by a linear steady-state phase. Graphs, tables, 10 references.—BTR. 7043

6.3.11, 8.8.1

Silver and the Platinum Metals. J. M. PRIE. *Metal Industry* (London), 83, No. 10, 188-190 (1953) Sept. 4.

Discussion of silver and the platinum metals in chemical engineering. Silver, resistant to chemical attack under a wide range of conditions, is the best metal for use in contact with halogens and halogen acids. Silver lining is an important application to chemical process equipment. Platinum and its alloys are used in the construction of electrodes for electrolytic oxidation, and for handling molten glass. Use of silver and platinum alloys as industrial catalysts is pointed out. Photographs.—INCO. 7143

6.3.11, 3.7.3, 3.7.4, 3.5.8

Electrolytic Cold-Working and Internal Friction in Palladium/Hydrogen Alloys. F. A. LEWIS, G. E. ROBERTS, AND A. R. UBBELOHDE. *Proc. Roy. Soc. (London)*, A, 220, 279-289 (1954) Jan. 7.

Hydrogen electrolyzed into palladium was found to affect internal friction, large increase being observed after charging or after removing some of the hydrogen by electrolysis. Ageing reduces internal friction to a limiting value without appreciable loss of hydrogen. Internal friction decrease obeys unimolecular rate law with velocity constant dependent on grain size of metal, decay being fastest in annealed specimens of large grain size in which limit of internal friction returns to value in pure palladium, although some 0.6 hydrogen atoms per palladium atom are present. Fine-grained charged specimens have internal friction decay to lower values. It is suggested that electrolysis produces large, but temporary, cold-working, accompanied by high internal friction and that rested alloys show permanent relaxation effects related to

initial grain size. Effect of hydrogen on Young's modulus and rigidity modulus of palladium, which are decreased on charging with hydrogen, is discussed.—INCO. 7345

6.3.12

Rhenium Metal—Its Properties and Future. L. W. KATES. Sylvania Electric Products, Inc. *Materials & Methods*, 39, No. 3, 88-91 (1954) March.

Rhenium in ductile form is being investigated for electrical contacts, thermocouple alloys and pen points. Alloys prepared by powder metallurgy methods composed of 50-99 rhenium with tungsten, nickel, molybdenum and others were used for pen points and have shown excellent wear resistance. Physical and mechanical properties, corrosion resistance, fabrication and applications are discussed. Illustrations, tables. 2 references.—INCO. 7550

6.3.15, 3.2.3, 3.8.4

The Oxidation of Titanium at High Temperatures in an Atmosphere of Pure Oxygen. A. E. JENKINS. Commonwealth Scientific and Industrial Research Organization, Univ. of Melbourne, Australia. *J. Inst. Metals*, 82, No. 5, 213-221 (1954) Jan.

The oxidation of titanium has been investigated in the temperature range 600 to 925°C. at an oxygen pressure of 700 mm. of hydrogen. The process of oxidation was followed by determining the gain in weight of separate specimens after various periods. The distribution of oxygen between the scale and remaining metal core was determined in the temperature range in which physical stripping of the scale was possible, and in such instances an examination of the oxidation products was undertaken. The scales were found to be porous to oxygen and the oxidation process has been shown to occur at the metal oxide/metal interface. A glancing-angle x-ray-diffraction technique was used to establish the nature of the scales and surface layers on the metal cores; the rutile modification of titanium dioxide was the only oxide observed in the scales. The surface layers of the metal cores were found to be composed of titanium-oxygen solid solutions, the surface concentrations and internal oxygen gradients of which were dependent on the oxidation temperature. A mechanism has been suggested for the oxidation of titanium at high temperatures which involves the diffusion of oxygen within the metal core as an accelerating factor.—NSA. 7567

6.3.20

Resistant Materials—Zirconium. *Corrosion Prevention & Control*, 1, No. 1, 23-29 (1954) March.

Production by the Van Arkel Process and by the Kroll Process, fabrication, and physical and mechanical properties of zirconium are discussed. Tables illustrate excellent corrosion resistance of zirconium to various chemicals, including acids, bases and others. Comparative resistance to corrosion of tantalum, niobium, zirconium, and titanium is shown.—INCO. 7543

6.3.20, 3.7.3

Ductile Welding of Zirconium. F. G. COX. *Murex Rev.*, 1, No. 11, 245-261 (1953).

Alternating current and direct current welds made in zirconium sheet of various

thicknesses, using standard argon-arc equipment or plastic containers flushed with argon to exclude all air from the welding zone, were subjected to hardness, tensile, corrosion, and microscopical examinations. It was concluded that ductile welds can be made in thin sheet (approximately 0.030 in. thick), using standard equipment with an additional argon stream on the back of the weld; direct current welds have superior properties in this material. In sheets less than ¼ in. thick all air must be excluded by a box, and for sheets more than ¼ in. thick the argon must be purified. Four references.—MA. 7441

6.3.20, 5.9.4

Electron and Photocurrents in Thin Films of Zirconium Oxide. (In English). A. CHARLESBY. *Acta Metallurgica*, 1, No. 3, 348-354 (1953).

When voltages less than 90% of the growth voltage are applied to anodized zirconium specimens, the electric current through the oxide layer consists almost entirely of electrons. The electron current, i_e , is related to the field strength F by the equation $i_e = 2A \sinh BF$, where $A = A_0 \exp(-U/kT)$, $B_0 = ae/kT$, U and a are, respectively, the height and the half width of the energy barrier for electron flow, and have the values $U = 0.375$ eV., $a = 3.6$ Å. An oxide film maintained at voltage for long periods shows a marked reduction in A_0 . This aging phenomenon indicates that the electron current is associated with imperfections in the oxide film which gradually disappear. Experiments with graphite on the oxide surface showed the current was not primarily caused by impurities in the film. Photocurrents which are also electronic are observed when ultra-violet light is incident on the surface; they may be partly due to destruction of some space charges in the film. Film age does not affect the photocurrents.—MA. 7425

6.3.20, 5.9.4

Ionic Currents in Thin Films of Zirconium Oxide. (In English). A. CHARLESBY. *Acta Metallurgica*, 1, No. 3, 340-347 (1953).

Thin insulating oxide films were formed by anodizing zirconium in various electrolytes, including some, e.g. dilute sulfuric acid, which give porous films on aluminum. Aqueous ammonium borate solution was used for most experiments; the film thickness was measured by optical and capacity methods. The thickness was directly proportional to the formation voltage, but a tenfold increase in current increased the thickness by only 10%. The thickness was 20 Å/V. from the optical measurements and 21 Å/V. from the capacity measurements if the dielectric constant = 20. The ion current i_i is related to the electrostatic field across the film F by an equation $i_i = A_0 \exp B_0 F$, where A_0 , B_0 are constants at room temperature and $A_0 \sim 10^{-11}$ amp/cm² and $B_0 \sim 3.4 \times 10^{-6}$ cm/V. According to Mott's theory of oxidation, the value of B_0 corresponds to a value of 2.8 Å. for the barrier width opposing ionic flow. 4 references.—MA. 7426

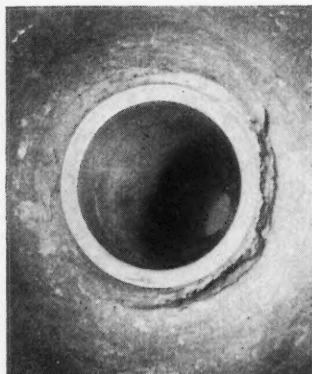
6.3.20, 6.3.15, 6.3.13, 6.3.16, 6.3.21

The Anodizing of Zirconium and Other Transition Metals in Nitric Acid. R. D. MISCH AND W. E. RUTHER. *J. Electrochem. Soc.*, 100, 531-537 (1953) Dec.

At 1 ma/cm² and concentrations of nitric acid exceeding 14 weight percent, zirconium was found to develop a low-

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End view of titanium diffuser. Note acid attack on cast iron flange.



Titanium steam jet diffuser easily passes 2 year acid test

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Ferric Chloride	0-30% at 100°C.	Process Piping,
Cupric Chloride	0-20% at 100°C.	Pumps, Valves,
Mercuric Chloride	All Conc. at 100°C.	Evaporators,
Aluminum Chloride	0-25% at 60°C.	Crystallizers,
Sodium Chloride	All Conc. at 100°C.	Kettles, Heat Exchangers
Sodium Hypochlorite	6% at 100°C.	Equipment for making bleaches
Chlorine Saturated Water	Room Temperature	Proportioning equipment
Wet Chlorine Gas	75°C.	Recovery equipment; electrolytic cells
Chromic Acid	10% and boiling	Plating equipment
Nitric Acid	0-70% at 100°C. 60% at 195°C.	Acid Heaters, Nitrators and Auxiliaries
Sulphuric-Nitric Acid Mixture	40% sulphuric, 60% nitric at 35°C.	
Nitric-Adipic Mixtures	38% nitric—17% adipic at 90-95°C.	
ORGANIC CHEMICALS		
Chloroacetic Acid	100% at 100°C.	Chemical synthesis; equipment in manufacture of pharmaceuticals
Dichloroacetic Acid	100% at 100°C.	Chemical synthesis; equipment in manufacture of dyes

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resistance oxide layer. Titanium, hafnium, niobium, tantalum, and tungsten showed a high resistance at this current even in 70 weight percent acid. Graphs, tables, diagram. 20 references.—BTR.

7099

6.3.21, 5.9.4

The Anodic Behaviour of Antimony. S. E. S. EL WAKKAD AND A. HICKLING. *J. Phys. Chem.*, **57**, No. 2, 203-206 (1953).

The anodic polarization of antimony in acid and alkaline solution was studied, mainly using the cathode-ray oscillograph. The following features were observed: 1) in weak acid and alkaline electrolytes, an antimony anode can be rendered passive at moderate current density; initially a relatively thick layer of Sb_2O_3 forms on the electrode under which a thick film of Sb_2O_5 is later pro-

duced; 2) at very low current density intermediate formation of Sb_2O_4 can be detected; 3) in strong acid and alkaline electrolytes in which the trioxide is soluble, no passivation occurs; and 4) reduction of the anodically formed oxides does not take place on cathodic polarization before hydrogen evolution, although deposition of antimony from solution may occur.—MA.

7514

6.4 Non-ferrous Metals and Alloys—Light

6.4.2, 5.9.4

A New Protective Coating Chemical for Aluminium Paint Ind. Mag., **68**, No. 7, 17 (1953) July.

The American Chemical Paint Company has produced a new type of Alodine

designated as Alodine No. 1200. This forms an amorphous mixed metallic oxide coating of low dielectric resistance that provides high corrosion resistance for unpainted aluminum. In addition it forms an excellent paint bond that approaches closely the high quality obtained with the earlier types of Alodine. Alodine No. 1200 is specifically recommended for coating wrought products that are not to be painted or to be only partially painted and for coating casting and forging alloys whether or not these are to be painted.—ALL.

7103

6.4.2, 5.9.4

Ionic Current and Film Growth of Thin Oxide Layers on Aluminium. A. CHARLESBY. *Proc. Phys. Soc. (B)*, **66**, No. 4, 317-329 (1953) April.

Describes part of a series of investigations into the electrical properties of thin insulating oxide layers formed electrolytically on aluminum. Limited to a study of ionic current and resultant film growth. 16 references.—BTR.

7256

6.4.2, 6.3.6

Aluminum for Copper: Greater Corrosion Risks? H. A. LIEBHAFSKY AND E. W. BALIS. *Gen. Elec. Res. Lab. Gen. Elec. Rev.*, **56**, No. 3, 12-16, 61 (1953) March.

For exposure to ordinary atmospheres and to distilled water, the natural film of aluminum furnishes complete protection. But increased protection for different situations is available through anodization. Under certain conditions where cells may occur that contain a heavy metal like copper, localized corrosion can be disastrous. Even this situation can be met if cell action is prohibited by eliminating any one of the four essentials. Alclad alloys too find extensive application because they carry added insurance as the coating of aluminum or anodic alloy is consumed when corrosion takes place while the core is protected. Evidence shows that aluminum or alclad alloys can be substituted for copper without necessarily increasing corrosion hazards as long as the oxide film remains intact. Table.—INCO. 7192

6.4.2, 6.3.15, 6.3.20, 3.6.6

Marine Exposure Tests on Titanium-Aluminum and Zirconium-Aluminum Couples. *Light Metals* (England), **16**, No. 184, 223 (1953) July.

Notes are reproduced on preliminary corrosion tests carried out by Saunderson-Roe (Anglesey) Ltd. on limited quantities of un-alloyed titanium and zirconium sheets. The tests were carried out in order to ascertain whether electrolytic action would have detrimental effects when the new material is joined to light alloy. Specimens were prepared by riveting samples to thin sheets of A4D sheeting. The three samples were tied to a stake in the Menai Straits so that the periods of immersion in sea water and exposure to the atmosphere were roughly equal. The exposure period was two months. Details of the specimens are as follows: Specimen A, Titanium riveted to A4D sheeting, with zinc chromate paste between faying surfaces; Specimen B, Zirconium riveted to A4D sheeting, with zinc chromate paste between faying surfaces; Specimen C, Titanium riveted to A4D sheeting, no jointing compound being used. A visual inspection of the specimens showed that when either titanium or zirconium is used in conjunction with aluminum alloys in any composite assembly involving a joining system such as that used

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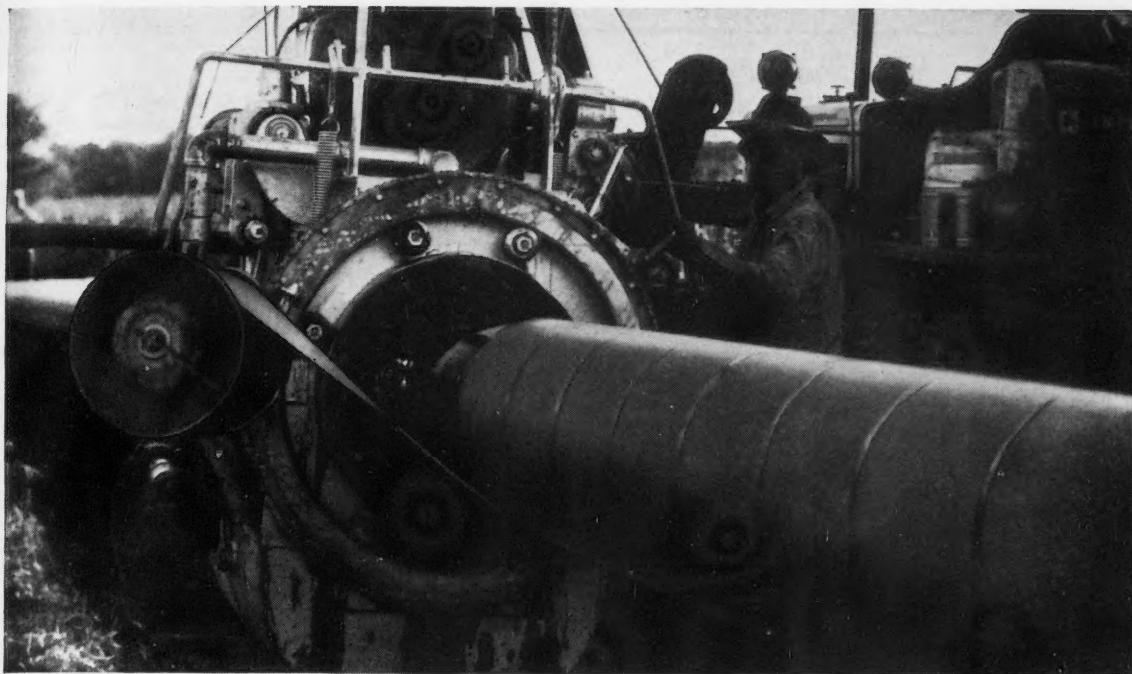
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here, and which might be used in practice, full precautions are probably necessary.—ALL. 7105

6.4.3, 3.4.6, 6.4.4, 6.3.19, 6.3.2

Action of Anhydrous Hydrobromic and Hydriodic Gases on Beryllium and Its Homologues in the Second Column of the Periodic Table. JEAN BESSON and GABRIEL VIVET. *Compt. rend.*, **236**, No. 18, 1788-1790 (1953).

The action of hydrobromic and hydriodic gas on beryllium is identical with that of hydrochloric previously described [Besson, *Bull. soc. chim. France*, **17**, 1175 (1950) Nov.-Dec.] Up to a certain temperature the metal is completely protected by a halogen film, and the protection ceases only with the sublimation of the film. For magnesium, zinc, and cadmium, the protection is less effective, and if the metal is powdered the attack begins sooner.—MA. 7392

6.4.4

Finishing Systems for Magnesium. H. A. BARBIAN. *Precision Metal Molding*, **11**, No. 12, 59-63 (1953) Dec.; *Modern Metals*, **9**, No. 11, 66-68, 70-71 (1953) Dec.

Paper presented at 9th annual meeting of the Magnesium Association, Nov., 1953. Basic requirements, cleaning, preventing galvanic corrosion, finishing systems in current use (painting after chemical pre-treatment, bright dips, black chemical finishes, electroplating with copper/nickel/chromium), serviceability of finished parts.—BNF. 7434

6.4.4

The Preparation and Properties of Magnesium Alloy Sheets of Controlled Impurity Content. H. G. COLE, A. E. L. TATE, AND B. WALTERS. *J. Inst. Metals* (London), **82**, Pt. 1, 25-31 (1953) Sept.

Three types of magnesium-alloy sheets in different grades of iron content have been prepared to determine the mechanical properties and corrosion-resistance of the sheets: 1) 1.7% manganese (corresponding to AM503); 2) 3.5% aluminum, 1% zinc (AZ31); and 3) 6.5% aluminum, 1.5% zinc (AZ61). Sheets of the type AZ31 and AZ61 showed poor corrosion resistance in the ordinary-purity grade and very high resistance in the high-purity grade. The mechanical properties of the aluminum containing sheets were good and independent of iron content. Sheets of the type AM503 showed a very high corrosion resistance but the mechanical properties were rather poor. Protective treatments were much more effective on sheets of high-purity aluminum-bearing alloys than on those of ordinary purity.—ALL. 7455

8. INDUSTRIES

8.4 Group 4

8.4.5, 7.2

Atomic Energy Production Requires Nickel-Plated Pipe. E. ALTHOLZ. *Machinery*, **60**, No. 7, 166-172 (1954) March.

A thin layer of nickel keeps processing pipes and fittings in atomic energy installations free from contamination by highly corrosive and radio-active gases. Pipe, made of carbon steel up to 40 ft. in length, ranges from 20 to 54 inches in inside diameter. Making and nickel plating of the pipe at a western New York plant is traced. Photographs.—INCO. 7445

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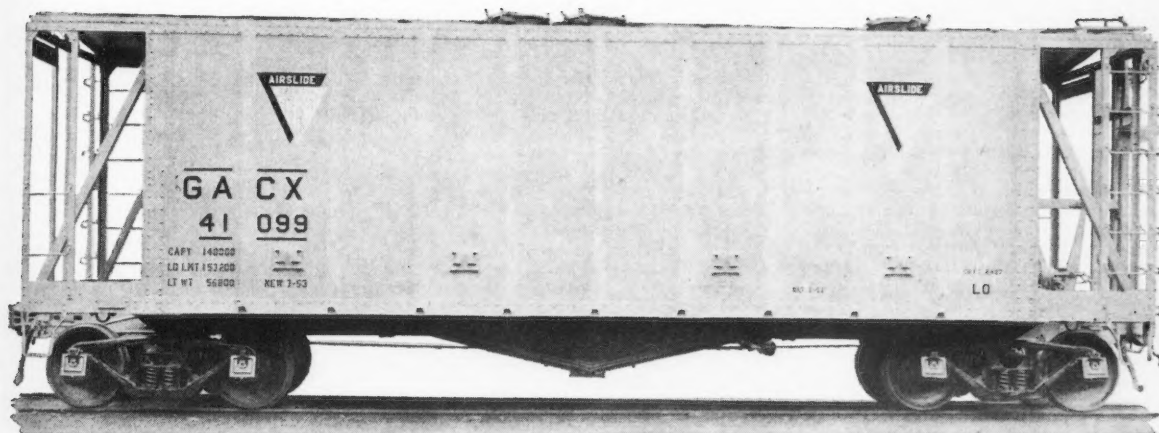


Photo courtesy General American Transportation Corporation

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8.4.3, 5.3.2

Clad Steel in Petroleum Equipment. ALBERT HOERSCH, JR. *Petroleum Processing*, 8, 700-703 (1953) May.

Describes cases of when to use and when not to use clad steel in processing units. Discusses welding and fabrication. Tables, diagrams.—BTR. 7009

8.4.3, 5.8.2

Is Your Plant Corroding? E. W. WALLACE. Shell Oil Co. Paper before Nat. Gas Assoc. Am., 32nd Ann. Conv., Houston, April 29-May 1, 1953. *Oil Gas J.*, 52, No. 3, 201-202+ (1953) May 25.

Corrosion in gas-handling equipment was observed in almost all instances where appreciable amounts of liquid water can be removed from the system. The severity of corrosion at these points is determined to a large extent by the amount of acid gases or the amount of air which is available. Treatment with corrosion inhibitor is used in some plants. Pits $\frac{1}{2}$ - $\frac{3}{4}$ in. deep in the cast steel headers of condensers and solution coolers were found.—INCO. 7182

8.4.3, 5.8.4, 1.2.2, 5.8.2

Condensate Well Corrosion. Book, 203 pp., 1953. Natural Gasoline Association of America, 422 Kennedy Bldg., Tulsa, Okla. (Per Copy—\$6.00.)

There are eighteen chapters each relating to the problems incident to corrosion in gas condensate wells. The work represents the accumulated data of 10 years' investigations by the Natural Gasoline Association of America's Condensate Well Corrosion Committee. In addition there is presented much useful information of economic nature, experimental procedure, laboratory vs. field experience correlation, ratings of the efficiencies of various systems of control and numerous case histories which enable the corrosion engineer faced with a condensate corrosion problem to compare others' experience with his own case.

The chapter headings, which are sufficiently explicit to indicate content are as follows: "History of Gas Condensate Well Corrosion Committee," W. F. Lowe; "Economics of Gas Condensate Well Corrosion," T. S. Zajac; "Criteria of Corrosiveness," H. L. Bilhartz and H. E. Greenwell; "Chromate Inhibitors," Jerry R. Marshall; "Organic Inhibitors," H. E. Waldrip; "Neutralization-Type Inhibitors," H. E. Waldrip; "Tubular Goods," F. A. Hunter; "Tubing Calipers," W. F. Oxford, Jr.; "Inhibitor Injection Methods and Practices," P. P. Spafford; "Well Completion Methods," H. L. Bilhartz and H. E. Greenwell; "Metallurgical Factors," F. A. Prange; "Laboratory Studies of Film Formation," Edward C. Greco; "Acidity of Condensate Well Waters," D. A. Shock; "Laboratory Studies on Corrosion in Carbon Dioxide and Organic Acid," R. B. Chesney; "Polar Constituents of Well Streams," Louis J. Hillenbrand, Jr.; and "Field Histories," Morris Bock.

An appendix lists laboratory methods useful in condensate well corrosion and a short discussion on corrosion control practices used by 26 companies surveyed by the committee. 7173

8.4.3, 5.9.2

How Chemical Cleaning Makes Money. J. T. BROWNING. *Petroleum Refiner*, 33, 131-132 (1954) Feb.

Case history of profitable application of chemical cleaning to restoration and cleaning of entire section of refinery. Photographs, diagram.—MR. 7247

8.4.3, 7.4.2, 7.6.8, 4.6.6

Casebook of a Corrosion Chemist. MAXEY BROOKE. Phillips Oil Co. *Petroleum Refiner*, 32, No. 8, 131-132 (1953) Aug.

A group of reports on unusual corrosion problems in a refinery and their subsequent solutions is presented.

Condenser-tube sheets: Active corrosion, subsequently identified as galvanic corrosion, occurred on the water side of the steel tube sheets of condensers where admiralty tubes were rolled in. As a solution to the corrosion problem, naval brass or naval brass plated tube sheets were installed.

Low-pressure reboilers: In reboilers for a deisobutanizer tower at a hydrogen fluoride alkylation unit, there was a general metal loss in all steel parts in contact with the steam condensate, particularly in the pass. Concentrations of 15 ppm. octadecylamine injected into the steam supply reduced iron content from as high as 175 ppm. to 2 ppm. The presence of any hydrocarbon in the steam would, however, make this treatment ineffective.

Fouled hydraulic oil: The filter screens in the hydraulic system operating the slide valves on a fluid catalytic cracking unit became clogged with iron oxide in a few days, making valves inoperative. Sorbitan monooleate was added to make a 0.05% solution. Corrosion was eliminated and screens remained clean.

Black-iron water pipe: War shortages made it necessary to use black iron instead of cast iron pipes in a potable water system. Corrosion of these pipes was excessive, resulting in red water and unpleasant taste. This was remedied by diverting the water flow through a chemical pot filled with molecularly dehydrated phosphate; flow was regulated to give a phosphate concentration of 5 ppm. in the pump discharge.

Reboiler tube ends: After 6 months operation, the steel tube ends at the outlet section of the condensate pass of a gasoline stabilizer reboiler had lost up to 75% of their original thickness where rolled into the tube sheet. Even by rotating the bundle 180° tube life was estimated to be less than 18 months. A vent was installed and a small amount of steam was continuously vented carrying with it the noncondensable gas. After three years service, the tubes showed no metal loss on the steam side.—PDA. 7413

8.4.3, 8.9.3, 5.4.5, 5.8.2, 3.3.4

Combating Corrosion, A Special Symposium. *Oil Gas J.*, 52, No. 41, 122-130, 132, 134-136, 141-143, 145-150, 152-156, 159-160, 162-164 (1954) Feb. 15.

Includes "Corrosive Oil and Gas Areas in the United States," D. A. Shock; "How to Get More Value From Paint," William T. Thies; "Protecting the Pipe-Line Protection," Frank B. Burns; "Management's Stake in Corrosion Mitigation," Lewis Finch, Jr.; "New Light on Asphalt Pipe-Line Coatings," H. C. McAninch; "How to Sell Management on Corrosion Mitigation," Ted L. Canfield; "Cold-Applied Coal-Tar Coatings," W. F. Fair, Jr.; "Organic Inhibitors in Oil and Gas Wells," P. D. Muir; "Semi-polar Organic Inhibitors Check Corrosion," Charles M. Blair; "Microbiological Corrosion," J. Bennett Clark; "Cathodic Protection for Pipe Lines," B. J. Whitley, Jr.; "Fundamental Electrochemistry of Corrosion," Bernard O. Heston; "Good Design Now Will Stop Corrosion Later," F. A. Prange; "Hot Coal-Tar Coatings Approach Ideal," N. T. Shi-

del. Maps, diagrams, tables, photographs, graphs. 16 references.—MR. 7325

8.4.5, 4.7

New Tests Prove Materials for Nuclear Power Plants. R. F. KOENIG. Knolls Atomic Power Lab. *Iron Age*, 172, No. 8, 129-133 (1953) Aug. 20.

Results of static corrosion tests of most common materials including iron, steel, stainless steels, cast iron, copper-base alloys, nickel and nickel alloys, and others, in a number of liquid metals, such as sodium, sodium-potassium, lithium, magnesium and others are listed. After a material shows good resistance to attack in static tests, dynamic tests and the effect of stress are investigated. If the stress-rupture life in sodium is equal to that in air, and there is no metallographic indication of intergranular attack, the material is considered fully resistant to stress corrosion.—INCO. 7095

8.5 Group 5

8.5.3

Corrosion of Carbon Steel in Aluminum Sulphate Solution: On the Corrosion of the Knife of Jordan Engine at Paper-Mill. S. MORIOKA. *J. Japan Inst. Metals*, 17, No. 6, 283-287 (1953) June.

This experiment was conducted to study corrosion of carbon steel knives in the Jordan Engine which treats the pulp solution containing aluminum sulfate, rosin soap, etc., of pH values ranging from 4.5 to 5.2. The carbon steel specimens (0.3% carbon and 0.8% carbon) were rotated in water at varying r.p.m. (0-1400) and pH of water (3.2-6.5), and corrosion loss of the specimens was measured. The corrosion rate of carbon steel in aluminum sulfate solution increased gradually with the increase in acidity at constant r.p.m., but was far less than in sulfuric acid solution with the same pH value, and at the same r.p.m., the rate was about 1/10 of the values found in the latter solution. This is due to the inhibitive action of positively charged colloidal particles of aluminum hydroxide which was produced by the hydrolysis of aluminum sulfate solution and was adsorbed on the cathodic area of the local cells of corrosion. Cupric ions in the solution markedly accelerated the corrosion by acting as a depolarizer for hydrogen and moreover producing galvanic corrosion due to the metallic copper reduced on the steel and these effects increase in r.p.m. Therefore a pipe of copper or copper alloy should be avoided as conduit-pipe to carry the pulp solution at a high speed into a Jordan Engine. 12% chromium stainless steel was immune against the solutions under the conditions mentioned above.—JSPS. 6995

8.5.3, 6.6.8, 7.2

How Plastic Piping May Be Used in the Pulp and Paper Industry. B. W. BENDER. U. S. Rubber Co. Paper before Am. Pulp & Paper Mill Supts. Assoc. Dinner Mtg., Michigan Div., Kalamazoo, Feb. 18, 1954. *Paper Trade J.*, 138, No. 12, 30, 32, 34 (1954) Mar. 19.

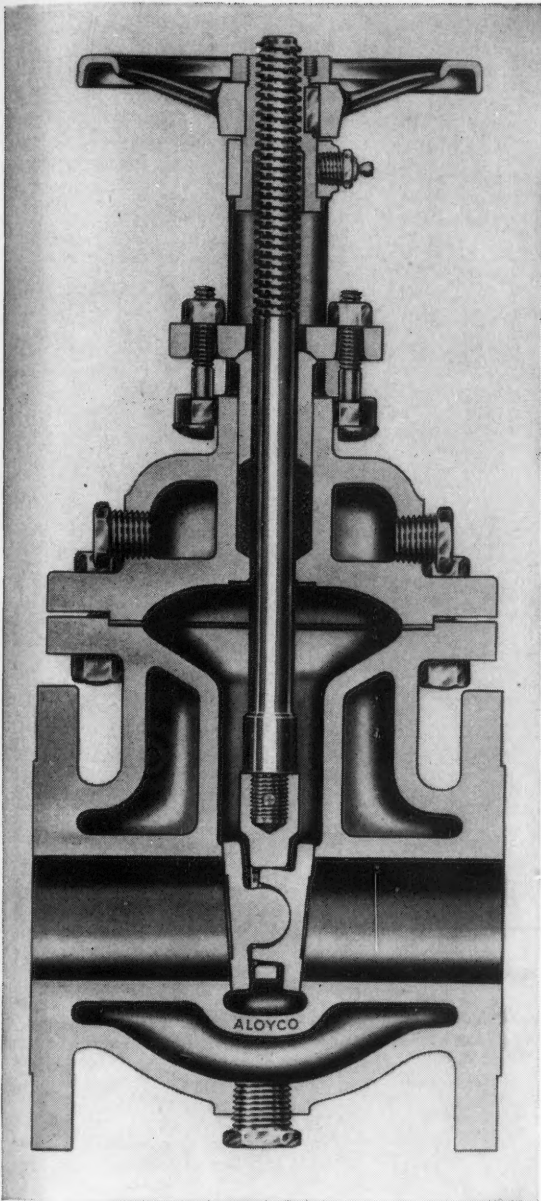
In uses where limitations in tensile strength, working pressures and temperatures are not restrictive, plastic pipe is economical because of its resistance to corrosion and chemical attack, light weight, ease of installation, high flow rate and long life. Properties, advantages

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Cross-section shows how jackets extend to edge of flanges and include stuffing boxes on this Aloyco 1105 Jacketed Gate Valve. Also shown are the non-fouling, ball-and-socket split-wedge disc and mar-proof rocker-type gland plate and follower.



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Now- fully jacketed valves put the heat on slow-moving corrosives

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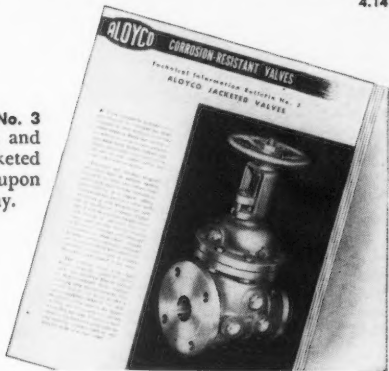
Then you're in line to benefit from the heat-holding design of Aloyco jacketed Gate, Globe and Check valves. Besides having all the Aloyco features shown at left, they're the only high alloy valves on the market to be *completely jacketed*.

They keep valves at higher temperature than steam tracing systems, and provide more uniform, less hazardous heating than thermal electric methods. You'll find them especially useful in line processing of rosin, resins, tars or tar oils, phthalic or maleic anhydrides, molten sulphur and other viscous liquids.

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and limitations of polyethylene, cellulose acetate butyrate (Tenite II), vinylidene chloride (Saran), polyvinyl chloride, fiberglass-reinforced polyester, styrene acrylonitrile copolymer blends (Uscolite) are given. Tables.—INCO. 7235

8.8 Group 8

8.8.1

Nickel Alloys Applied Industrially in the Distillation of Coal. (In French). B. DE BORDE. *Rev. nickel*, 19, No. 2, 37-45 (1953) April-June.

Use of various nickel-containing stainless steels and Monel metal for corrosion resistant plant in the industry. Relative corrosion resistance is discussed.—BNF. 7423

8.8.1

Gasification of Lignite in a Commercial-Scale Pilot Plant. Progress Report for 1947-48. A. C. BURR, J. C. HOLTZ, A. W. KOTH, AND W. H. OPPELT. U. S. Bureau of Mines, Report of Investigations No. 4940, Feb., 1953, 28 pp.

Discusses useful life of outer metal retort tube as influenced by corrosion under a wide range of operating conditions. Also emphasizes gas generation with high ratio of hydrogen to carbon monoxide in both divided and continuous annuli.—BTR. 7427

8.8.1, 3.5.3

Corrosion and Erosion in the Synthetic-Fuels Demonstration Plant. G. D. GARDNER AND J. T. DONOVAN. Bureau of Mines. Paper before ASME, Fall Mtg., Chicago, Sept. 8-11, 1952. *Trans. Am. Soc. Mech. Engrs.*, 75, No. 4, 525-532; disc. 532-533 (1953) May.

Corrosion and erosion during two years of operation of the first American coal-hydrogenation plant are described as well as solutions and improvements developed. Isolated cases of localized corrosion fatigue, caustic embrittlement, stress corrosion, and pitting are described. Use of AISI Type 316 stainless minimized the effect of hydrogen attack in high-pressure equipment except where design temperature was exceeded. High-pressure lines and valves handling oil-solid mixtures containing absorbed gases showed greater corrosion rates. Tables and photomicrographs.—INCO. 7379

8.8.5

How To Cut the Cost of Finishing Your Product. C. RAYMOND SYER, SR. *Ind. Finishing*, 29, 28-30+ (1953) Jan.

Covers selection of equipment, removal of scale, dust, tar, and heavy soil; setting up and maintaining process controls; features of cleaning phosphating machine; and evaluation tests and cost data.—BTR. 7330

8.8.5

Measure Surface Roughness. *Precision Metal Molding*, 12, No. 3, 63-64 (1954) March.

New tool, the S22 microfinish comparator for establishing controlling and checking microfinish on metal parts, is produced by electro-forming pure nickel. Stainless steel blocks are used as master patterns against which nickel electroforms are made. Tool does not corrode, gives a series of flat surface specimens for visual tactual comparison, and is based on SAE and ASTM standards. Produced by Baptist Machine Co.—INCO. 7361

8.8.5, 5.9.2, 6.6.4

Design for Longer Pickling Equip-

ment Life. J. F. REVILOCK. *Steel*, 133, 84, 86, 88 (1953) Dec. 21.

Discusses applications of carbon and graphite in wet and dry pickling equipment. Gives design tips and performance data. Diagrams.—BTR. 7238

8.8.5, 5.9.4

Versatile Steel Carburizing Process Provides Low Cost, Hard Surface Parts. J. B. FROBLUM AND H. W. HIEMKE. Calif. Alloy Products Co. *Western Metals*, 12, No. 3, 44-47 (1954) March.

Mechanics of carburization, types of gas carburizing furnaces, gas generators, and gas chemistry are discussed. With the development of gas carburizing furnaces, alloys were developed that can resist the high temperatures and embrittlement of carburization, and have enough strength at the operating temperature. An alloy of approximately 35% nickel and 15% chromium, remainder iron, either cast or wrought, is successful for most of the carburizing furnace parts. In some parts lower alloy content is satisfactory while in others alloy content as high as 80% nickel, 20% chromium and no iron was used. However, even in quenching service, 35% nickel, 15% chromium with good design provides satisfactory life. Illustrations.—INCO. 7337

8.8.5, 6.2.5

Iron Lung for Sick Metals. *Steel*, 133, No. 10, 132 (1953) Sept. 7.

By using a full muffle, gas-fired hydrogen atmosphere furnace with a water jacketed cooling chamber, called an iron lung, Gen. Metal Products Co.'s Type 305 18-8 stampings which turned black or green through oxidation are again bright and scale free with their original sparking finish. Furnace is also used to heat treat stainless steels in the 400 series. Illustrations.—INCO. 7315

8.9 Group 9

8.9.1

Strategic Metals in Aircraft Construction. R. SMALLMAN-TREW. *Canadian Metals*, 16, No. 2, 18, 20, 22 (1953) Feb.

Discusses the various steels and light alloys used for different parts of aircraft, the alloying elements used in them, and the metals used for corrosion protection, etc.; possible substitutes.—BNF. 7214

8.9.1, 3.5.9

Chemical Coatings. *Aviation Week*, 58, No. 1, 72 (1953) Jan. 5.

Chemical coatings to protect aircraft metals are being produced by Markal Co. Markal's S-R heatproof coating is used on exhaust stacks, blowers and mufflers—protecting the metals from scaling and corrosion in temperatures up to 1850°F. The D-A coating withstands corrosive conditions caused by steam, salt spray, hot acids and mild alkalis at temperatures up to 600°. Both coatings may be applied by spray, brush or dip.—INCO. 7378

8.9.1, 6.4.2

Harvey Aluminum Develops Newest Aircraft Alloy. *Am. Metal Market*, 60, No. 208, 10 (1953) October 27.

A new structural aircraft aluminum alloy, designated HZM 100, and having mechanical properties of 100,000 lb./sq. in., has been developed by the Harvey Aluminum Co. The new alloy will provide aircraft extruded components of

lesser cross sectional dimensions, and having maximum resistance to corrosion, with consequent savings in weight.—ALL. 7487

8.9.3

Protection Against Corrosion of Pipelines. (In Hungarian). FERENC ZACHEMSKI. *Banyász. Lapok* (Hungarian Journal of Mining), 8, No. 11, 559-565 (1953) Nov.

Describes corrosion and protection of a Hungarian pipeline built in 1940-1942. Discusses examinations; onset of corrosion; course and repairs effected; causes of corrosion; galvanic reactions; and measures against them. Tables, diagrams, graphs. 7 references.—BTR. 7194

8.9.3, 2.4.3

Ultrasonic Inspection...for Internal Pipe-Line Corrosion. S. K. GALLY. Southern Cal. Gas Co. Paper before Pacific Coast Gas Assoc., Santa Barbara, 1953. *Oil Gas J.*, 52, No. 13, 61-62 (1953) Aug. 3.

Field tests show that ultrasonic equipment provides a practical and accurate means for locating and measuring corroded areas inside a pipe line and for discovering defects in the pipe wall. Because of its narrow ultrasonic beam, pits can be detected and their depths measured. Procedures for rapid scanning and handling rapid scanning data are still to be developed.—INCO. 7153

8.9.3, 5.2.1, 1.2.2, 4.5.1

Economic Aspects of Corrosion Control. D. H. LEWIS AND O. C. MUDD. Shell Pipeline Corp. Paper before Corrosion Group, Society of Chem. Ind., Nov. 13, 1953, London. *Chemistry & Industry*, No. 4, 93-100 (1954) Jan. 23.

The material, opinions and conclusions contained in this paper are drawn from the experience in operating 6100 miles of buried pipelines comprising Shell Pipe Line Corporation's crude oil and products pipe-line system. The economic aspects of corrosion control, and the role of cathodic methods in a properly balanced program for the protection of pipe-lines and similar underground structures are discussed. Tables and graphs.—INCO. 7263

8.9.3, 5.4.10, 5.2.2

Prevention of Corrosion on Underground Pipeline. *Commonwealth Engr.*, 40, No. 7, 294-295 (1953).

A steel pipeline is coated with asphalt and fiber glass; cathodic protection is provided by attaching magnesium-alloy anodes—8/mile.—MA. 7460

8.9.4

Arc Cutting on Railroad Cars. W. C. HENZLIK. *Welding Engr.*, 39, No. 3, 23 (1954) March.

Hopper cars carrying an acid commodity are built of stainless-clad sheets with unloading doors on the car bottom of cast stainless. Damaged parts of the sliding doors were cut out with an electric arc-compressed air cutting torch. Replacement parts were fabricated and welded back into the doors with stainless electrodes.—INCO. 7374

8.9.4, 4.3.6

Does Antifreeze Destroy Cars. *Ry. Age*, 136, No. 3, 22-23, 26 (1954) Jan. 18.

B & L E assays results of tests of the corrosion from calcium chloride applied to coal and ore to prevent lading freezing to the car. Trays of copper steel



Bitumastic Enamel being machine-applied to a section of "The Biggest Inch."

"The Biggest Inch" gets the best barrier against corrosion—BITUMASTIC ENAMEL

• "The Biggest Inch" was recently completed in Texas. 465 miles long, this pipe line is one of the largest single carriers of crude oil in the United States. A river of oil rolls through this 26-inch line at the rate of 301,000 barrels daily.

Exterior surfaces of this steel line are protected against corrosion by Bitumastic® Enamel—a protective coating that has proved its worth. Many oil and gas pipe lines, protected by Bitumastic Enamel 20 and

30 years ago, are still in excellent condition today.

There are many properties that make Bitumastic Enamel the best barrier against corrosion. Here are some: 1) High resistance to water; 2) High electrical resistance; 3) High resistance to soil chemicals; 4) Stability under soil stress; 5) Lasting ductility.

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and Cor-Ten steel were used in the 4-year test. Loss of weight due to corrosive action was much greater in the copper steel trays than in the Cor-Ten steel trays. Treatment with calcium chloride accelerated corrosion of both materials. Photographs and tables.—INCO.

8.9.4, 6.2.4

Corrosion Problems in Railway Equipment. Factors in Hopper-Car Design on Virginian. L. W. DOGGETT. Paper before 4th Corrosion Conf., Wrightsville Beach, May 19-21, 1953. *Ry. Locomotives & Cars*, 127, No. 7, 56-57 (1953) July.

Virginian uses Cor-Ten steel plates in the construction of hopper coal cars and gondola cars in large quantities. Visual inspection after 5½ years showed that the corrosion of these cars is not as severe as similar cars of the same age built with open hearth copper-bearing steel plates.—INCO. 7200

8.9.4, 7.6.4, 4.6.2

Methods to Increase the Efficiency of Steam Locomotives. Paper before International Ry. Congress, London, May, 1954. *Ry. Gazette*, 100, No. 7, 178-179 (1954) Feb. 12.

Summary by C. T. Long of replies from railways in English-speaking countries on methods to increase the efficiency of steam locomotives. South African railway had trouble with cracking of the stress corrosion type of boiler shells of certain locomotives. In bad water districts, S.A.R. replaces copper by steel when firebox renewals become necessary. Very little corrosion or pitting in boilers using softened water was reported. Corrosion is reported of pure lead used in plugs resulting from high alkalinity as a limited factor in the extension of period between washouts. Tannin is used to minimize corrosion, while tests were carried out with electroplating the plugs with a certain degree of success. Little scale formation is reported where feed water enters the boiler. All the reporting railways use chemical treatment of boiler feed water in some form.—INCO. 7327

8.9.5

Painting of Ships. W. FORWERK. *Schiffbautechnik*, 3, 58 (1953); *J. Brit. Shipbuilding Res. Assoc.*, 8, No. 5, 323 (1953).

The importance of painting as a means of reducing corrosion in shipbuilding is discussed. In the case of prefabricated small craft, where the assembly time on the ships is 10-12 days, it is impossible to prepare the surfaces with the same care that is employed on larger vessels, and even quick-drying paints will not harden in time. Mill-scale is frequently removed by sand- or shot-blasting. Shot-blasting penetrates the mill-scale and dents the plating, if shot-blasting is prolonged until all the mill-scale is removed, the surface will be covered with small craters which rapidly become rusty. Sand, on the other hand, will splinter when it hits the surface, and tear off the mill-scale, leaving the surface completely smooth. Both brushing and spraying may be used for painting ships, spraying being mainly employed for internal work. Care must be taken to ensure adequate ventilation when spraying in enclosed spaces.—RPI. 7512

8.9.5, 5.4.2, 4.4.6

The Preservation of Oil Tanker Hulls. J. LAMB AND E. V. MATHIAS. *Trans.*

North East Coast Inst. Engrs. & Shipbuilders, 69, No. 6, 289-316 (1953) April.

Scale removal and painting of hull exteriors. Protection of steel cargo tank interiors by surface coatings (sprayed aluminum and zinc unsatisfactory; most promising general-purpose material was an inorganic zinc-rich paint with sodium silicate as medium), atmosphere control, inhibition, and cathodic protection (magnesium anodes successful in butane tanks). Tables, graphs, micrographs.—BNF. 7188

8.10 Group 10

8.10.2, 8.8.5, 1.6

Non-Ferrous Foundry Metallurgy. Book, 6" x 9¼", 497 pp., 1954. McGraw-Hill Book Co., Inc., 330 West 42nd St., New York 36, N. Y. Per Copy...\$12.50.

This is a comprehensive collection of information on foundry metallurgy by British experts in the field. The first 156 pages of the book are devoted to a consideration of fundamental information on properties of liquid metals, solution of gases, solidification and other material of significance in casting. Succeeding chapters on technology, properties and testing of castings and casting alloys, all by British writers, cover what appears to be recommended practice in England and Europe with respect to castings. Most of the appended chapter references are to European sources.

Two references to corrosion are made, these consisting of brief discussions of the three principal classes of corrosion affecting castings. Reference to corrosion-resistant characteristics of some alloys, such as Hastelloy, for example are included, although these are not noted in the subject index. The writers believe castings are not as likely to be attacked by corrosion as wrought shapes.

The book is a well-rounded, illustrated, treatise on foundry principles, practices and techniques. Much data are tabulated. 7275

8.10, 2, 8.8.5, 1.6

Current Russian Metallurgical Texts. III. C. A. ZAPFFE. *Metal Progress*, 64, No. 6, 88-90 (1953) Dec.

In continuation of two previous similar articles five Russian books are briefly reviewed, dealing with introductory metallurgy, metals and alloys in machine construction, metallurgy of copper and nickel, corrosion and resistant materials and rare metals.—BNF. 7190

Statement Required by the Act of August 24, 1912, as Amended by the Acts of March 3, 1933, and July 2, 1946 (Title 39, United States Code, Section 233) Showing the Ownership, Management, and Circulation of CORROSION, Published Monthly at Houston, Texas, for 31 September, 1954.

1. The names and addresses of the publisher, editor, managing editor, and business managers are: Publisher, National Association of Corrosion Engineers, 1061 M & M Bldg., Houston, Texas; Editor, Ivy M. Parker, P. O. Box 1743, Atlanta, Georgia; Managing Editor, Norman E. Hamner, 1061 M & M Bldg., Houston, Texas; Business Manager, A. B. Campbell, 1061 M & M Bldg., Houston, Texas.

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Sworn to and subscribed before me this 15th day of September, 1954. Ann Graham. (My commission expires June 1, 1956).

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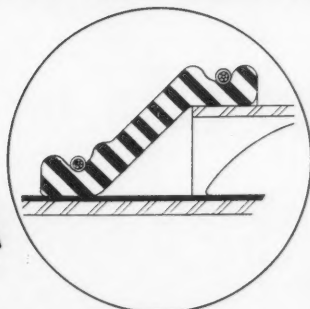
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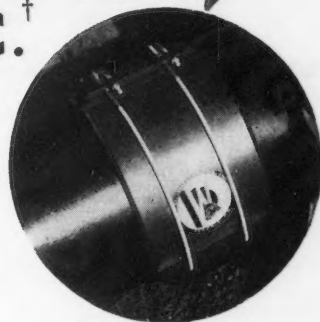
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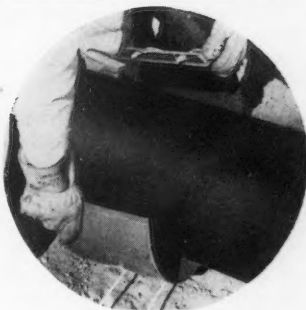


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New STYLE 2 THINSULATOR

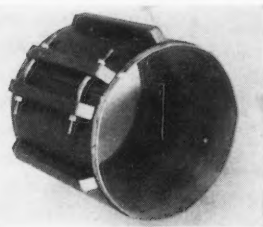
Similar to "BT" Insulator except with steel skids throughout. Excellent for soft coatings — but does NOT center pipe in casing.



SPECIAL FOR DISTRIBUTION AND GATHERING LINES

New DO-NUT BUSHING

Thick, synthetic rubber ring dimensioned to grip the pipe when hammered into casing. Ideal for pipe of 6" size and smaller.



STYLE 1 THINSULATOR

Thin Insulator with rubber-lined steel band for 10" and smaller pipe in casing only 2" larger. Welded steel skids on bottom only where joint is bolted.

*Specific features of devices illustrated on this page are covered by U. S. Patents or Patents Pending.

†A manufacturer who renders FREE service in the field to help insure correct installations.

T. D. Williamson, Inc.



**THE PIG WITH THE POKE
CLEANS PIPE LINES**

P. O. BOX 4038
TULSA 9, OKLAHOMA



News about **COATINGS for METALS**

Metallic Organic Decorative Protective

Protective coatings take on tough jobs

Sprayable plastisols offer seam-free thick-film protection

Any metal equipment which can be uniformly heated at 350°F can now be protected with a thick, sprayed-on vinyl plastisol coating. Provided by Unichrome Plastisols, such films resist acids, alkalis, alcohols, water, salt and other corrosive solutions. The heavy build-up, up to 20 mils per coat, assures no weak or thin spots to give corrosion a toe hold. The spraying assures a seam-free surface as thick or as thin as economy and service conditions dictate.

These features are obtained in Unichrome 5300 Series Coatings. They often permit ordinary metals to be used instead of costly alloys.

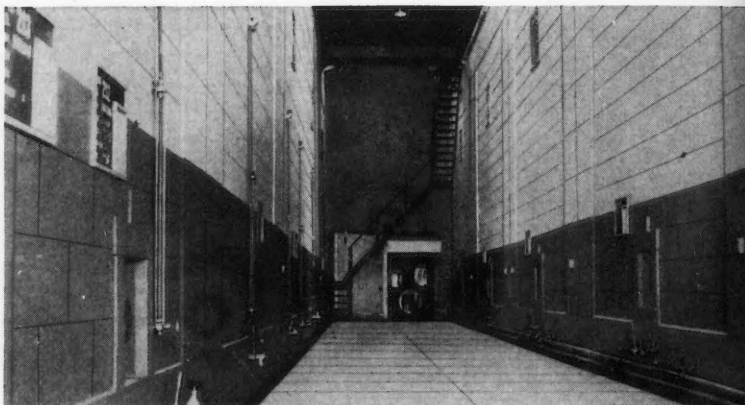
Phenolic coatings applied by specialists

Phenolic coatings give a good account of themselves in the battle against corrosion. Where facilities exist for baking large equipment, Ucilon Coating 1501 stands ready to deliver a hard finish resistant to acids, solvents, oils, water and other paint-damaging agents.

Lack of such facilities need be no barrier to utilizing phenolics. Many strategically located companies specializing in coating application now exist. Equipment shipped to these specialists will be returned with the tough, long-life protection provided by Ucilon 1501. Ask us for the names of these specialists—or for more information on Ucilon 1501.

UNITED CHROMIUM, INCORPORATED

100 East 42nd Street, New York 17, N. Y.
Detroit 20, Mich. • Waterbury 20, Conn.
Chicago 4, Ill. • Los Angeles 13, Calif.
In Canada:
United Chromium Limited, Toronto 1, Ont.



Ucilon Coating System, lining tanks used in beverage processing, prevents contamination and protects flavor

Applications once thought impractical now virtually routine with Systems of Ucilon® Protective Coatings

Uses for chemical-resisting protective coatings keep widening. Where good results were once unobtainable, Ucilon Coating Systems now deliver outstanding protection against corrosion plus unusually long service life in constant contact with strong chemical solutions.

MAKING TANKS IMPERVIOUS

50,000-gallon, concrete, fuel storage tanks are now lined with a Ucilon Coating System applied over special latex, protecting against attack by the aviation. gas and guarding against fuel contamination.

The answer to many brine corrosion problems has been found in a new Ucilon System that provides thicker than ordinary vinyl coatings. Applied to brine clarifier tanks by a leading chemical producer, this system is in perfect condition after 14 months service. Before, nothing ever

lasted more than 60 to 90 days.

Another Ucilon Coating System has solved a tough problem in protecting interiors of tank cars carrying saturated ammonium nitrate solution. One user reports no failure even after two years service. Ucilon protection saves shippers of these fertilizers the high cost of special alloy tank cars.

THE KEY TO SUCH RESULTS

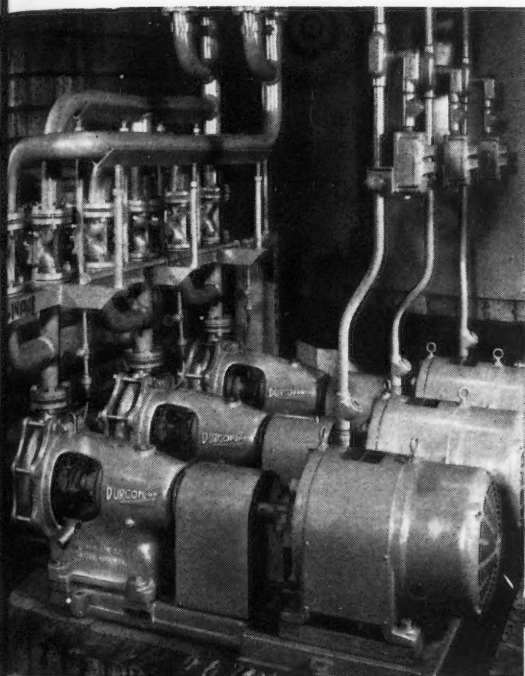
Specialized corrosion control has made the difference. Sixteen systems of Ucilon Protective Coatings provide the variety of specialized materials and coating combinations needed to beat hundreds of corrosives. They offer the properties required for contact with strong solutions and fumes. They block corrosion, save maintenance, equipment and money.

See more details by sending for Bulletin MC-8.

©Trade Mark

For reliability in America's great
chemical plants

DURCOPUMPS



Durcopumps pictured in service at

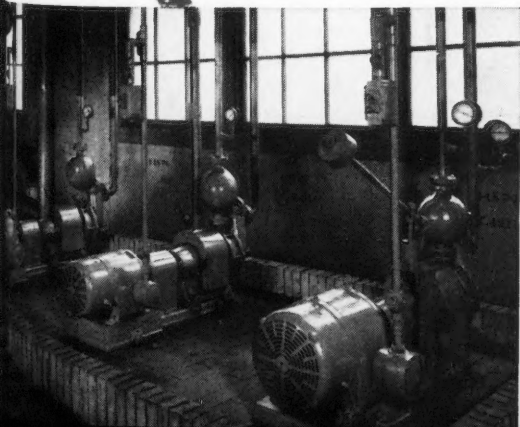
AMERICAN Cyanamid COMPANY

The Bound Brook, New Jersey Plant

The Duriron Company has been serving American Cyanamid Company for many years by providing chemical service equipment to handle their severe corrosives safely and reliably.

The Bound Brook plant of American Cyanamid Company is a primary source of pharmaceuticals, dyestuffs, pigments, rubber chemicals, intermediates, and other products for the chemical processing industry. They use Durcopumps for their process pumps.

We take pride in serving the country's leading industrialists. We are particularly proud that many of the really top companies turn to DURCO first when they have a corrosion problem.



THE DURIRON COMPANY, Inc.
Dayton 1, Ohio

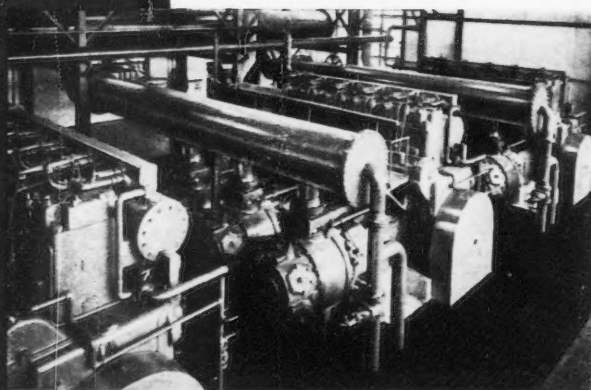


For YEARS of surface protection
in corrosive atmospheres, use
these lower-cost

MODIFIED (EPOXY RESIN BASE) *

DEVTRAN^{*}

FINISHES!



Modified epoxy Devran is ideal for many applications in refineries, chemical plants and factories where corrosive fumes are encountered.

- Extraordinarily tough
- Fast drying
- Easy, conventional application

*Devran, the original epoxy resin.

And—for superlative corrosion resistance against strong acids and alkalis, there's
no finish like 100% Epoxy DEVTRAN CHEMFAST!

Until Devco pioneered paints with epoxy resins, the painting of surfaces exposed to strong acids and alkalis involved constant and costly maintenance. And where impact and friction also were present, the paint just couldn't take it. Devran changed things!

DOUBLE-DUTY DEVTRAN

(Interior and Exterior)—Modified Devran finishes cost less than 100% Devran Chemfast, yet they contain the correct proportion of epoxy resin to give long-lasting protection against corrosive fumes, plus maximum toughness, resilience and impact resistance.

Double-Duty Devran is one of these modified epoxy finishes, equally suitable for inside or outside use. It is extremely durable. It has very high hiding qualities; goes on easily by brush or spray, and dries very quickly. Use Double-Duty Devran wherever actual contact with corrosive liquids does not regularly occur.

DEVTRAN QUICK-DRYING ENAMEL

This modified epoxy Devran is an all-purpose oil and abrasion-resistant finish with a hard, high gloss. Its very rapid drying qualities make it ideal for machinery, pipe identification, safety colors, etc. in a busy plant. Normally one coat gives complete hiding. Its durability under abuse is almost unbelievable!

DEVCO
PAINT

It will pay you to write or wire for complete
information about Devco Devran Finishes.



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